TRADITIONAL KNOWLEDGE AND FISH BIOLOGY: A STUDY OF BERING CISCO IN THE YUKON RIVER DELTA, ALASKA

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TRADITIONAL KNOWLEDGE AND FISH BIOLOGY: A STUDY OF BERING CISCO IN THE YUKON RIVER DELTA, ALASKA

A

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Abstract

Relatively little is known about the biology of whitefishes (subfamily Coregoninae) in Alaska. To address this shortcoming, I combined social and biological science methods to examine whitefish in the Yukon River delta, Alaska. This study had two objectives: (1) to collaborate with Yup'ik subsistence fishers in sharing their knowledge of whitefish; and (2) to describe the life history of Bering cisco *Coregonus laurettae*. In August 2004, interview participants discussed Yup'ik traditional knowledge of whitefish. Participants shared knowledge of Bering cisco and other whitefish species. Interviews demonstrated the need for greater awareness of traditional knowledge, and the importance of communicating this knowledge with scientists. In addition, 120 Bering ciscoes were collected in August 2005 and 2006 with gill nets in the Yukon River delta, Alaska. Bering ciscoes ranged in fork length from 146 to 490 mm (mean = 321 mm) and in weight from 32 to 735 g (mean = 304 g). Fish ranged in age from 0 to 6, with one age-11 individual observed. Diet analysis showed that Bering ciscoes fed primarily on sticklebacks. My study records important social and biological data regarding Bering cisco, linking ethnography and fish biology as a means of investigating this poorly understood species.

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Introduction

Understanding Alaska's fisheries requires a diverse set of disciplines. Fisheries scientists pursue their research through various fields of study, including the biological, physical, and social sciences. As a result, current research examines many facets of the role of fisheries in Alaskan life. Fishing supports Alaskans and their communities in a variety of ways. It provides essential wage employment opportunities in remote locations distant from the world's population centers. Fishing and processing jobs bring revenues to economically depressed communities, supporting families, services, and infrastructure. Sport-fishing opportunities provide residents and visitors valuable recreational experiences, and support local vendors and guiding services. Perhaps most importantly, fish are an essential and sustainable source of food for thousands of Alaskans, without which residents would rely on expensive and often less nutritious products shipped into the State from distant markets. For Alaska Native peoples in particular, fishing traditions are an important link to their heritage, culture, and spirituality.

This study applied ethnographic and biological research methods to examine whitefish *Coregonus* spp. in the coastal Yukon River delta, Alaska. Ethnographic research took place in Scammon Bay, Alaska, a Yup'ik Eskimo community where many families pursue traditional subsistence fishing, hunting, and gathering activities. I selected Scammon Bay because of my familiarity with the community, primarily due to the fact that my spouse is originally from that community. Scammon Bay is located on the Bering Sea coast, approximately 94 km south of the mouth of the mainstem of the Yukon River. There are 528 residents, 97% of whom identify as Alaska Native

(ACDCIS 2011). The economy is mixed, consisting principally of subsistence activities, barter, and wage employment from mostly local government and education jobs. Scammon Bay subsistence activities include harvests of large and small terrestrial mammals, marine mammals, marine fishes, freshwater fishes, marine invertebrates, migratory waterfowl, upland game birds, sea birds, bird eggs, berries, herbs, marine and freshwater aquatic plants, roots, and tubers (F. Charlie, Scammon Bay, Alaska, personal communication).

Among the variety of fish species harvested by residents of Scammon Bay, a substantial portion consists of whitefish. Harvested whitefish species include inconnu *Stenodus leucichthys*, broad whitefish *Coregonus nasus*, humpback whitefish *C. pidschian*, Bering cisco *C. laurettae*, least cisco *C. sardinella*, and round whitefish *Prosopium cylindraceum*. Common Yup'ik names for these fish are *ciiq*, *qaurtuq*, *cingiikegleq*, *imarpinraq*, *iituliq*, and *cev'eq*, respectively. As determined by traditional knowledge interviews conducted in this study, the most desirable whitefish species targeted in Scammon Bay is Bering cisco. This species is anadromous and is distributed throughout coastal western Alaska from Oliktok Point, east of the Colville River delta, in the north to Bristol Bay in the south, as well as in Cook Inlet (McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980; Mecklenburg et al. 2002). Bering cisco spawning migrations begin in May and June in the Yukon, Kuskokwim (Alt 1973a; Morrow 1980), and Susitna rivers (ADFG 1981), and spawning occurs during September and October, when adults broadcast spawn in mainstem river channels over gravel substrates (ADFG 1981; Brown 2000). Whether spent adults overwinter in rivers or return to coastal marine habitats following spawning is not known. Juveniles drift downstream after emergence from gravel in the spring and are distributed to coastal marine and freshwater habitats (Naesje et al. 1986; Martin et al. 1987; Shestakov 1991). Juveniles are reared in these habitats until they reach maturity as early as age four (R. Brown, U.S. Fish and Wildlife Service [USFWS], personal communication). Patterns of Bering cisco spawning are not known. Of all the Yukon River coregonids, Bering cisco is likely the most abundant species in the river. Although this observation has yet to be recorded in the published literature, ongoing research suggests that Bering cisco outnumber all other whitefish species combined in the Yukon River during whitefish spawning migrations (R. Brown, [USFWS], unpublished data).

Scammon Bay is a community of cultural and economic systems that are closely linked with issues of natural resource management. As a result, I determined that participants in this study and their community would benefit from better understanding and improved management of Bering cisco. Interest in Bering cisco arose during traditional knowledge interviews that I conducted with subsistence fishers in Scammon Bay in August 2004. The primary goal of these interviews was to give subsistence fishers an opportunity to share their knowledge and experience regarding whitefish in the region, and have their interviews recorded for the benefit of the participants, their community, and future generations. The secondary goal of these interviews was to allow participants to guide and advance the understanding of life histories of various species of whitefish. Interview participants were selected on the basis of recommendations by individuals known to be active subsistence fishers. Interviews were open and semi-directed, guided by a prepared list of possible questions and discussion topics. These interviews were conducted in English and Yup'ik. Topics of discussion included identification and nomenclature of whitefish species, seasonal patterns of migration and abundance, traditional activities of harvest and travel associated with whitefish, processing and consumption of whitefish, feeding behavior of Bering cisco, and apparent effects of changing beaver *Castor canadensis* populations on whitefish.

Subsistence fishers interviewed also indicated that Bering cisco is likely the most abundant whitefish species in the Scammon Bay area as well as the most highly valued whitefish. Interview participants demonstrated an extensive knowledge of the habits and general life history of this species. My review of the interview recordings directed me to develop a biological investigation of the life history and ecological role of Bering cisco in coastal marine habitats. I also determined through a literature review and correspondence with whitefish biology experts, that little is known about Bering cisco populations as well as their life history. As a result, I made the determination that an ethnographic and biological study of Bering cisco would be valuable to biologists, fisheries managers, and rural Alaskan coastal subsistence fishermen and their communities.

An aspect of this study included participant observation of subsistence fishers. In doing so, I personally observed substantial subsistence harvests of Bering cisco in the study area. For example, one day in August 2004, I observed six households harvesting, processing, and hanging approximately 100 to 200 Bering ciscoes per household on fish drying racks. I also observed families setting nets during subsistence harvest excursions to obtain Bering cisco as a fresh food source while they traveled. While I observed harvests of Bering cisco in Scammon Bay, there are other regions of rural Alaska where this has also been documented. These areas include Hooper Bay and Kwigillingok (Stickney 1984), the middle Kuskokwim River (Charnley 1984), Kuskokwim Bay (LaVine et al. 2007), and Kotzebue Sound (Georgette and Shiedt 2005).

Despite Bering cisco's apparent abundance and importance in subsistence harvests in rural Alaska, fisheries scientists have not thoroughly investigated the life history of this species. My study attempts to address this shortcoming by extending background scientific knowledge of Bering cisco life history. Results from my study will assist future researchers in continuing investigations of this poorly understood species.

The results of this study are relevant to current Bering cisco management. Since 2005, the Alaska Department of Fish and Game (ADFG) has managed an experimental commercial whitefish fishery in the lower Yukon River (Fabricant 2008). The current harvest limit is set at 4,536 kg of Bering cisco and least cisco; however, fishers and processors in the area have expressed an interest in raising that harvest level tenfold to 45,360 kg. Fishery managers have indicated that the ADFG recognizes the need for more studies of Bering cisco populations. As a result, the ADFG is utilizing commercial harvest surveys and biological sampling to establish baseline life-history and population data for this area (S. Buckelew, ADFG, personal communication). Various biological and stock characteristics are being recorded and analyzed before any expansion of the fishery will be considered. The results of my study could be directly applied to management of commercial and subsistence harvests of Bering cisco in the region. Another important recommendation of my study is that the ADFG should incorporate local subsistence fishers in traditional knowledge investigations that can supplement biological data collections.

With my descriptions of Yup'ik fishers' reliance on Bering cisco, managers may recognize that traditional knowledge must be an integral part of managing such a complex fishery. For example, lower Yukon River fish processors have made the controversial claim that Bering cisco is not utilized by local subsistence fishers (Demarban 2010). My study unequivocally contradicts this point of view, and establishes the fundamental importance that the species holds within the local culture and economy. The ADFG has recognized the likelihood that subsistence fishers are harvesting Bering cisco (Demarban 2010), but has yet to attempt to confirm it through an extensive investigation such as my study.

The use of the term *traditional knowledge* in my thesis essentially follows the definition of *traditional ecological knowledge* described by Berkes (1999). Traditional knowledge is shared across generations through cultural heritage and represents an evolving and adaptive body of knowledge, practice, and belief regarding human and natural ecology (Berkes 1999). This phenomenon of traditional knowledge was evident in conversations about whitefish with residents of Scammon Bay. I discovered that when people communicated with me about whitefish, not only did they describe fish, they also discussed many aspects of traditional and contemporary Yup'ik life. People shared their knowledge of whitefish anatomy, feeding ecology, and migrations. In addition, they shared knowledge of local physical and ecological phenomena in their descriptions of geography, tides, sea ice, river ice, and river substrates. They also described whitefish in terms of human ecology, with discussions of traditional harvests, family history, seasonal movements between camps, food processing and consumption, sharing of food, respect of and dependence upon whitefish, sustainability of cultural and natural resources, and the education of young people. These discussions demonstrated the foundations of traditional Yup'ik ways of knowing. They were holistic in their approaches to understanding natural and human systems. This compared with the culture of Western science, which reduces the natural world to specific descriptions of its constituent parts and mechanisms. One culture's view is abstract, the other's concrete, and both are unique in their descriptions of the natural world (Levi-Strauss 1966).

Perhaps a third culture should be noted, that of natural resource managers, which is particularly significant within the context of social and biological investigations of fisheries resources in Alaska. The people of Scammon Bay and many of Alaska's rural residents are dependent upon natural resources for their food. Interview participants' descriptions of Bering cisco and other whitefish always included discussions of food customs. For example, three species of whitefish are named according to the way in which they are processed and consumed. Other discussions included the intimate connections that fish like Bering cisco had in people's survival. Mary Ann Sundown, the eldest interview participant, described how her family's annual cycle of migration between fish camps was guided by whitefish as an essential food resource. "*Imarpinraqs* (Bering cisco) were our first dry fish in the spring. When we ran out of [salmon] they kept us from starving." (Mary Ann Sundown) Such expressions of reliance upon fish as a food resource that sustains families are not always evident in management protocols, but need to be recognized. If fisheries managers and traditional fishers collaborated more in rural settings like Scammon Bay, the two groups might develop stronger connections and sounder management schemes together.

This thesis contains two chapters that document the social and biological science investigations of my research. Each chapter describes in detail my research methods and results. These chapters appear to divide my research into two discrete studies, one ethnographic and one biological. It is important to note that my overall process was more holistic than the format of this document may suggest. My personal reflections on this study are that it tells a story of learning about whitefish, Bering cisco in particular, in the region of Scammon Bay, Alaska. The story began when I talked with traditional Yup'ik fishers about whitefish and recorded some of these conversations. I soon learned that Bering cisco was the most desirable whitefish species due to its high nutritional value and preferable taste. In August 2005 and 2006, I collected biological samples of Bering cisco while observing and participating in subsistence whitefish harvests. Several interview participants and others guided me in the field, where I experienced the customs and skills practiced by Yup'ik fishers harvesting Bering cisco. The whole story of Bering cisco described in this thesis includes knowledge and experience gained from three field seasons of conversations, fishing excursions, and biological fish collections, as well as several months of laboratory analyses.

Chapter 1 describes the ethnographic portion of this study, which introduces the research framework and objectives of the traditional knowledge study. This chapter also documents the methods applied to interviews and participant observations. I also describe the variety of topics and questions addressed in the interviews, as well as the participants' insights into the human ecology of subsistence whitefish harvests in the Scammon Bay area. I conclude the chapter by discussing the social and cultural aspects of this Yup'ik traditional knowledge study of whitefish, and its implications for fisheries research and management.

In Chapter 2, I describe several biological phenomena which advance our understanding of Bering cisco life history. I discuss the age-frequency distribution, length, and weight data as a means of establishing methods for evaluating Bering cisco growth and population in the study region. This chapter also discusses my investigation of the diet and principal forage of Bering cisco in coastal marine habitats. I also compare gill raker data from my specimens with those of previous studies (McPhail 1966; Bickham et al. 1997). The purpose of this is to provide morphological information which may be applied to future studies of the three known Bering cisco spawning stocks. Future researchers can apply these data to stock and recruitment analyses, estimates of relative abundance of age groups, mortality estimates, and other management protocols which are not currently rigorously applied to Bering cisco subsistence and commercial fisheries.

In my conclusion I demonstrate the value of collaborative documentation of traditional and scientific knowledge and the implications for local communities, scientists, and managers. I attempt to define ways in which these unique systems of understanding the natural world might complement each other, and build efforts to support each others' goals. I describe how my own approach to learning about human and biological dimensions of fisheries attempts to be inclusive of the knowledge and experiences of Yup'ik and Western scientific ways of knowing. As a result, I suggest ways in which fishers, researchers, and managers can cooperate and ensure sustainability of Bering cisco populations and other fisheries resources.

Chapter 1: Yup'ik traditional knowledge of whitefish and subsistence fishing in Scammon Bay, Alaska

Introduction

Caleb Pungowiyi, a Yup'ik elder from Savoonga, Alaska, once noted that scientists may develop a narrow view of a subject based on the knowledge they obtain from intensive research. He contrasted this narrow base with the broad knowledge that indigenous peoples have of the environment, a knowledge based on lifelong dependence upon local organisms and their habitats. The scientist makes many precise observations over a relatively short period of time, while the traditional user makes many general observations throughout a lifetime (Schneider 2001). As a result, each individual may have important knowledge which is unknown to the other and yet complementary to his or her understanding of many phenomena. As Pálsson (1998) observed, western practices of inquiry tend to ignore traditional and practical knowledge, separating these from and ascribing primacy to scientific understanding. Most contemporary systems of natural resource management continue to be dominated by scientific investigation. This is true despite the documentation of more holistic indigenous management schemes (Berkes 1999) as well as advances in scientific knowledge provided by traditional indigenous resource users (Georgette and Shiedt 2005).

The ethnographic record of this research project documents traditional knowledge of subsistence whitefish fisheries in Scammon Bay, Alaska, a Yup'ik community on the Yukon River delta. The objective of this study was to give subsistence fishers an opportunity to share their knowledge and experience regarding whitefish in the region, and have their interviews recorded for the benefit of the participants and their community. In addition, this project recognizes the potential contribution that experienced indigenous fishers can make in advancing the knowledge of whitefish life history and in assisting subsistence fishery management. This study also provides a potential model with which resource users, field biologists, and ethnographers can unify divergent experiences of the natural world into cooperative efforts of research and co-management.

Current research demonstrates the value of fisheries biologists seeking the cooperation of local fishers by documenting traditional knowledge and incorporating it into resource management planning (e.g. Freeman 1997; Berkes 1998; Berkes and Folke 1998; Robinson and Kassam 1998; Ford and Martinez 2000; Georgette and Shiedt 2005). This project was intended to begin such a process for the whitefish resources of the study region, which includes local fishers' knowledge of the resource as well as the scientific expertise of fisheries biologists. Prior to initiating a course of study integrating traditional and scientific knowledge, I recognized the need to be aware of certain factors which would affect the quality of my study outcomes on several levels.

One factor was to determine the benefits of my research outcomes. A primary concern which I had in developing this project was that my research should benefit the interview participants and the people of Scammon Bay. Current standards of scientific research involving human participants require that research informants derive benefit from their participation in any study (Penslar 1993). Benefits for participants must be determined by the nature of individual research projects. In traditional knowledge studies such as this, I felt that the Alaska Native research collaborators would likely benefit from cooperating in a fish biology study that helps to document baseline life-history data of poorly understood, albeit important, subsistence fish (Craig 1989; Chang-Kue and Jessop 1992; Reist 1997; Treble and Reist 1997; Georgette and Shiedt 2005). Such efforts would result in advancing all parties' overall knowledge of whitefish and potentially provide for better strategies for protecting these fishes as a natural resource. The documentation of the cultural value of this fishery and of subsistence practices is also likely of great importance to the people and future generations of Scammon Bay.

The lack of knowledge of basic whitefish biology and life history warrants further inquiry. One manner in which to address this concern is to begin a dialogue with knowledgeable fishers who rely upon whitefish as an important food resource. Their knowledge and understanding may reveal to scientists some previously unknown phenomena or introduce an alternative manner in which to study a problem. Traditional knowledge studies often demonstrate how the cooperation of traditional communities in scientific research can result in a novel understanding for the scientific community. One such study involved Iñupiat whalers of Barrow, Alaska who collaborated with physical scientists in a project that attempted to predict patterns of movements of nearshore sea ice in the Chukchi and Beaufort seas. The physical scientists' expertise introduced local whalers to methods of observing and predicting sea ice patterns with satellite and climatological data, which they found to be of value to their hunting practices. When whalers expressed their traditional and historical observations of nearshore ice, the scientists soon recognized the limitations of their own methods. Although satellite imagery presented two-dimensional representations of sea ice over a vast spatial scale, it lacked the third spatial dimension that local whalers were able to describe with Iñupiat terminology, and the fourth dimension of ice behavior over time. They shared with scientists their own personal knowledge and descriptions of observations of atmosphere, ice, ocean, and seafloor. This sharing enriched scientists' ability to see patterns within satellite images (Norton 2002; Norton and Gaylord 2004).

Additional benefits of traditional knowledge studies include the development of scientists' understanding of natural phenomena as indicated by study participants. In another equally revealing study, researchers and local fishermen of the Solomon Islands documented traditional knowledge of subsistence fisheries which refuted an earlier study's results. The first study determined that a local commercial baitfish harvest had no effect on the abundance of a subsistence target species of barracuda *Sphyraena* spp. that researchers believed did not prey on baitfish. The second study determined that the methods of the first failed to observe what local subsistence fishers knew, that barracuda did feed on commercially exploited baitfish. The first study limited observations of barracuda feeding ecology to daylight hours, but local fishermen harvested barracuda at night when they were feeding on the baitfish in question. Unfortunately, local management agencies, which regulated commercial fisheries, relied on the first, not the second broader study (Johannes et al. 2000).

These two examples demonstrate benefits obtained from research which combines traditional knowledge with western scientific methods. Indigenous groups benefit from a holistic and culturally sensitive inquiry into natural systems within their environment.

Western scientists benefit from insights gained by unique and somewhat profound indigenous perspectives. The latter study (Johannes et al. 2000) indicates an important factor which I determined could affect the quality of this study's outcomes. Historically, Alaska Natives and other indigenous peoples have been largely excluded from most management decisions, despite being precisely those who are most dependent upon sound resource management. The adoption of research methods which incorporate traditional knowledge, while potentially beneficial to indigenous communities, can actually result in a project's failure to grasp the nature of indigenous cultural, environmental, and spiritual points of view. Such failures arise when scientific researchers design projects that presume that traditional knowledge contributions from indigenous participants represent discrete natural history data specifically relevant to the study subject. Often, indigenous contributors regard the natural and cultural world holistically, and choose not to distill this understanding into separate fields of knowledge such as western scientists tend to do (Nadasdy 2003). Rather, indigenous peoples are more likely to refer to their knowledge as a way of life (Nadasdy 2003). This approach can further alienate indigenous communities when the researchers designing a project define the terms and limitations of a study (Cruikshank 1998). If researchers propose that the overall purpose of a project is to obtain and preserve traditional knowledge, then they are making the error of treating traditional knowledge as a set of discrete intellectual products completely separable from the cultural milieu that gives them meaning (Nadasdy 2003). My research attempted to resolve such issues by permitting interview participants to guide discussions of whitefish and subsistence activities, as well as by recording their approaches to understanding whitefish and related topics of ecology and their own cultural practices.

Although it is challenging to avoid distilling traditional knowledge into discrete data on a species population, both researchers and subsistence fishers have recognized the need to extend the basic biological understanding of whitefish in the Arctic and subarctic (Craig 1989; Freeman 1997; Berkes 1999; Georgette and Shiedt 2005; LaVine et al. 2007). The purpose of this study was to document traditional knowledge of whitefish in Scammon Bay, Alaska. During August 2002 in several informal conversations with Francis Charlie of Scammon Bay and Denis Shelden of Alakanuk, Alaska, I determined that some subsistence fishers of the Yukon River delta have an extensive and intimate knowledge of whitefish life history. This knowledge includes migration behavior, seasonal abundance, and seasonal habitat selection. During formal interviews, indigenous fishers of Scammon Bay described basic feeding ecology of Bering cisco *Coregonus laurettae*, in addition to a variety of recent changes in whitefish populations of the region. Interview participants also expressed their own questions and concerns regarding changes in whitefish abundance and the effects of an apparent increase in beaver *Castor canadensis* population. A review of the current biological literature revealed that these questions have yet to be carefully recorded or fully investigated within the study region of this project. Concern over increased beaver populations in the Yukon River delta has been noted by Maciolek (1989), and studied in the Yukon Flats region of Alaska by Anderson and Fleener (2001).

Many fisheries biologists agree that the basic knowledge of Alaska's whitefish species is incomplete and that more research in this field is necessary to develop responsible whitefish management practices. It is generally accepted by fisheries managers that whitefish represent a significant portion of subsistence fish harvests in rural Alaska. Whitefish are harvested by indigenous subsistence fishers throughout northern Alaska. Many studies have documented the importance of whitefish species as a subsistence resource in rural Alaska (Crawford 1979; Charnley 1984; Stickney 1984; Coiley-Kenner et al. 2003; Andersen 2007; LaVine et al. 2007). Georgette and Shiedt (2005) observed that Iñupiat people harvest thousands of whitefish every year from the waters of the Kotzebue Sound region, and that in the community of Shungnak whitefish comprised 31% of the total mass of locally harvested foods.

Both interview data from this study and my observations in Scammon Bay also indicate the importance of whitefish. Peter George (Scammon Bay, Alaska), a collaborator in this project, stated that "people can catch 100 or 200 pounds of *imarpinraq* (Bering cisco) in a day". George Smith (Scammon Bay, Alaska), another project collaborator, claimed that "all winter we'll catch [whitefish] by the fifty-pound sack". In August 2004, while conducting informal interviews in Scammon Bay, I observed the results of one day's harvest of Bering ciscoes at six different households. Each household had fish drying racks with approximately 100 to 200 Bering ciscoes each. Throughout the remainder of that summer, several families continued to catch Bering ciscoes, as was the case in the two consecutive summers.

The evidence cited above suggests that whitefish are a critically important subsistence food resource for the people of Scammon Bay and the Yukon River delta region. Subsistence fishers of Scammon Bay depend on their unique understanding of whitefish within their region. In turn, Yup'ik people's traditional reliance on whitefish as a source of sustenance is likely to be consistent with their profound understanding of other natural phenomena within the region.

Methods

This project was funded by the University of Alaska Fairbanks (UAF) School of Fisheries and Ocean Sciences Alaska Sea Grant College Program, a division of the National Oceanic and Atmospheric Administration. The Scammon Bay Traditional Council granted permission for traditional knowledge interviews to be conducted within their community. Research protocols involving human participants were reviewed and approved by University of Alaska Fairbanks Institutional Review Board (UAF IRB Protocol number 04-28; Appendix C).

In developing this project, I had preliminary discussions with experienced subsistence fishermen of the Yukon River delta region. From 22-24 August 2002 in Fairbanks, Alaska, I had several informal discussions with Francis Charlie of Scammon Bay and Denis Shelden of Alakanuk, Alaska, a Yup'ik community on the Yukon River delta. They discussed their general knowledge of the life histories of whitefish, which they frequently target as subsistence species. Using U.S. Geological Survey topographical maps (1:250,000) of the Yukon River delta, they also indicated locations relevant to a discussion of whitefish life history and harvest. The purpose of these discussions was to establish a preliminary understanding of subsistence fishing activities related to harvests of whitefish in the region, and to become familiar with the participants' interest in and knowledge of whitefish life history and biology. These conversations were open and non-directed. I had no prepared questions to ask them. They discussed any information or reflections that they desired to share.

I developed a research proposal to identify and interview individuals knowledgeable about whitefish in their region based on their experience of harvesting and processing these species. I chose Scammon Bay as the community in which to conduct these interviews based upon my social and familial connections with the village and my familiarity with the area and residents' seasonal habits there. For several years, I resided in the area. I have a basic knowledge of Yup'ik culture and a limited familiarity with the Yup'ik language. I also have knowledge of the typical subsistence livelihood due to my participation in such activities since 1992.

In order to identify culturally specialized informants with lifelong practical knowledge of subsistence fishing activities, I employed the techniques of respondent-driven sampling as described in Bernard (2006). One of the initial participants, Francis Charlie, a person whom I had known for more than ten years, became a key informant for this study. Francis is a very active hunter and fisherman, valued in the community as a respected elder and important cultural resource. After conducting three unstructured interviews, I asked him to recommend individuals living in Scammon Bay whom he believed had extensive experience as traditional fishers, hunters, and gatherers. Based on my familiarity with the community, I was able to confirm that the recommended participants were active in traditional subsistence hunting, fishing, and gathering. As an additional resource I asked the president of the Scammon Bay Traditional Council to recommend other potential collaborators. He and Francis Charlie recommended the same five individuals.

After identifying and obtaining the cooperation of the recommended participants, I began the ethnographic study. Traditional knowledge data collection occurred in one of two formats as discussed by McCracken (1988) and Huntington (2000). One format was the use of semi-directed interviews facilitated with an "Interview Guide" document as a guideline for discussion (Appendix A). With this method, discussions are prompted by the interviewer while the interview participant determines the progress and scope of the interview. The interviewer may use predetermined topics or questions to facilitate the interview process. The interview participants are free to discuss what they consider appropriate or meaningful. This interview format, while using a series of specific questions as a guide, is open and without a time limit (Huntington 2000; Bernard 2006).

Interview questions and topics addressed Yup'ik whitefish nomenclature, traditional and contemporary harvest practices, whitefish behavior and migrations, whitefish habitat selection, and characteristics of whitefish populations (Danko 1988). All participants gave verbal consent to be interviewed and signed an "Informed Consent" document. Six participants (Table 1.1) gave verbal consent to permit recording of their interviews and to give recorded copies to the University of Alaska Rasmuson Library, Alaska and Polar Regions Department, and signed an "Oral History Gift and Release" document. Interview participants were shown color

Table 1.1. Names of participants in semi-directed, recorded interviews in Scammon Bay, Alaska. Participant ages and dates interviewed are included.

Interview Participants	Age (years)	Date of Interview
George Smith	45	14 August 2004
Mike Utteryuk, Sr.	83	15 August 2004
Peter George	44	18 August 2004
Mary Ann Sundown	85	18 August 2004
Nathan Kaganak	80	19 August 2004
Francis Charlie	63	21 August 2004

photographs of whitefish species known to inhabit the study region (Figure B-1; Figure B-2) (Collier 1957; Harper 2002). This photo elicitation technique facilitated identification and discussion of the species of interest. Rebecca Charlie-Runfola provided translation and interpretation services when participants wished or required that interviews be conducted in Yup'ik. I conducted six semi-directed interviews (Table 1.1). Interviews took place in Scammon Bay in the participants' homes as well as in one participant's office and in another residence. The interviews were recorded on 80-minute Sony MiniDiscs® with a Sony MZ-B10® portable digital recorder. Recorded interviews were transported to Fairbanks, Alaska and stored in accordance with the UAF IRB protocol. They were translated by Rebecca Charlie-Runfola, transcribed, and coded for emergent themes. A digital copy of each interview was recorded on a compact disc and given to the respective participants.

The second format for discussing whitefish and other traditional knowledge topics with subsistence fishers was participant observation (Jorgenson 1989; Bernard 2006) and collaborative field work (Berkes 1999; Huntington 2000). I accompanied project participants as they traveled to various sites throughout the region for subsistence fishing, hunting, and gathering activities. Travel was usually by boat and occasionally on foot. On these excursions, participants discussed and explained the harvest activities they were undertaking, while I was able to observe and participate in the process. Collaborative activities and topics of discussion were most often related to the finding, harvesting, and processing of whitefish, in addition to whitefish life history, particularly that of Bering cisco. Each of these excursions included subsistence whitefish harvests using gill nets.

During this portion of the traditional knowledge study, participants were Randall Charlie, Francis Charlie, and Theresa Charlie of Scammon Bay, Roger Canoe of Nunam Iqua, Alaska, and Raphael Jimmy of Mountain Village, Alaska. Within the region of Scammon Bay in the Kun River drainage, observations and field work took place in the following locations: Kikneak and Tungpuk rivers, Ben Utteryuk's camp, and Qelliq (Figure 1.1). Observations and field work in the region of Black River, Alaska occurred at Francis Charlie's camp and Anaarciq (Figure 1.1). I recorded much of the traditional knowledge data in field notebooks when practical. These excursions took place in May, July, and August 2004, July and August 2005, and July and August 2006. Throughout this period, I spent a total of 29 days conducting participant observations. Excursions included at least two hours and as long as 14 hours of fishing and related activities. Latitude and longitude of whitefish harvest sites were recorded using a Garmin Etrex Vista® global positioning system instrument.

Results

This section provides a summary of the traditional knowledge interviews recorded in this study. Participants discussed several topics throughout the interviews. The majority of the topics were related to Yup'ik whitefish nomenclature, observed whitefish life-history characteristics and behavior, traditional and contemporary whitefish harvest practices, and the apparent increasing beaver population. Peter George's and George Smith's interviews were conducted in English. Interviews with Francis Charlie, Nathan Kaganak, Mary Ann Sundown, and Mike Utteryuk were conducted in Yup'ik. Fish

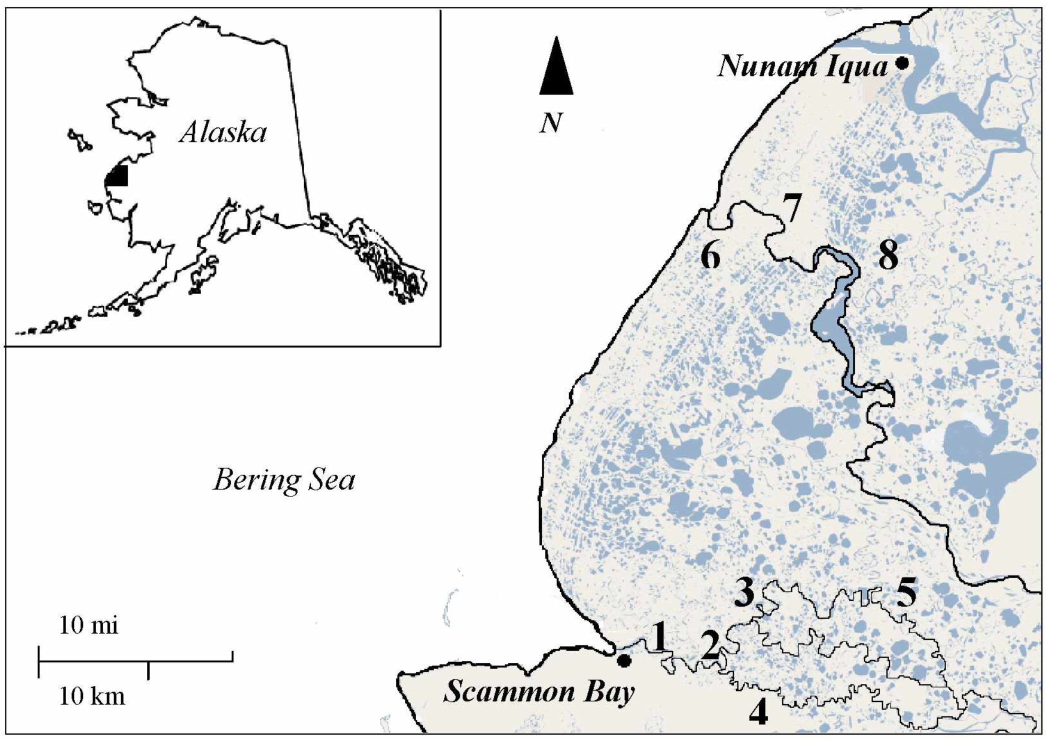

Figure 1.1. Map of Yukon River delta, Alaska, at the Bering Sea coast from the community of Nunam Iqua in the north to Scammon Bay in the south. Bering cisco sampling sites were located in the following locations: 1) Kun River, 2) Ben Utteryuk's Camp, 3) Qelliq, 4) Kikneak River, 5) Tungpuk River, 6) Francis Charlie's Camp, 7) Black River, 8) Anaarciq (Google Maps 2011; University of Arizona 2011).

names were transcribed in Yup'ik. This is for consistency and for the purpose of representing the common usage of Yup'ik names among all participants.

Yup'ik whitefish nomenclature

All participants in this study knew whitefish only by their Yup'ik names, except for inconnu which is also known by the English common name of sheefish. Participants indicated the presence of six different species of whitefish within the region: *ciiq* (inconnu or sheefish *Stenodus leucichthys*) (Table 1.2; Figure 1.2), *qaurtuq* (broad whitefish *C. nasus*) (Figure 1.3), *cingiikegleq* (humpback whitefish *C. pidschian*) (Figure 1.4), *imarpinraq* (Bering cisco) (Figure 1.5), *iituliq* (least cisco *C. sardinella*) (Figure 1.6), and *cev'eq* (round whitefish *Prosopium cylindraceum*) (Figure 1.7).

Photo elicitation techniques were used to identify the above whitefish species. Interview participants were shown color photographs of these species and asked to name or otherwise identify them. The photographs were approximately one quarter scale. All participants were able to name humpback and broad whitefish, inconnu, and Bering cisco immediately with the use of the color photographs provided. Four individuals were able to name, distinguish, and describe round whitefish and least cisco with the same photographs. These four individuals were the eldest of all participants, ranging in age from approximately 63 to 85 years of age. Some had difficulty seeing the relatively small images of the latter two species. When given sufficient time to observe the images with a magnifying glass and with the assistance of objective descriptions of the species' significant characteristics (e.g., mouth shape and orientation, fin color, cross-sectional shape), the interview participants were able to name them. Other interview participants

Table 1.2. Scientific, common English, and common Yup'ik names for several species of fish of the Yukon River delta, Alaska, which were discussed with interview participants in Scammon Bay, Alaska, August 2004.

Genus species	English common name	Yup'ik name(s)
Coregonus pidschian	humpback whitefish	*cingiikegleq*
Coregonus nasus	broad whitefish	*qaurtuq*
	large, old broad whitefish	*akakigneq*
Stenodus leucichthys	inconnu, sheefish	*ciiq*
Prosopium cylindraceum	round whitefish	*qassaayaq, cev'eq,*
Coregonus laurettae	Bering cisco	*imarpinraq*
Coregonus sardinella	least cisco	*iituliq*
n/a	small whitefish (i.e. round whitefish, Bering cisco, least cisco)	*neqyagaq*
n/a	small whitefish eaten raw (i.e. round whitefish, Bering cisco, least cisco)	*qassaayaq, qassarkaq*
Pungitius pungitius	ninespine stickleback	*quaruq*
Gasterosteus aculeatus	threespine stickleback	*quaruq*

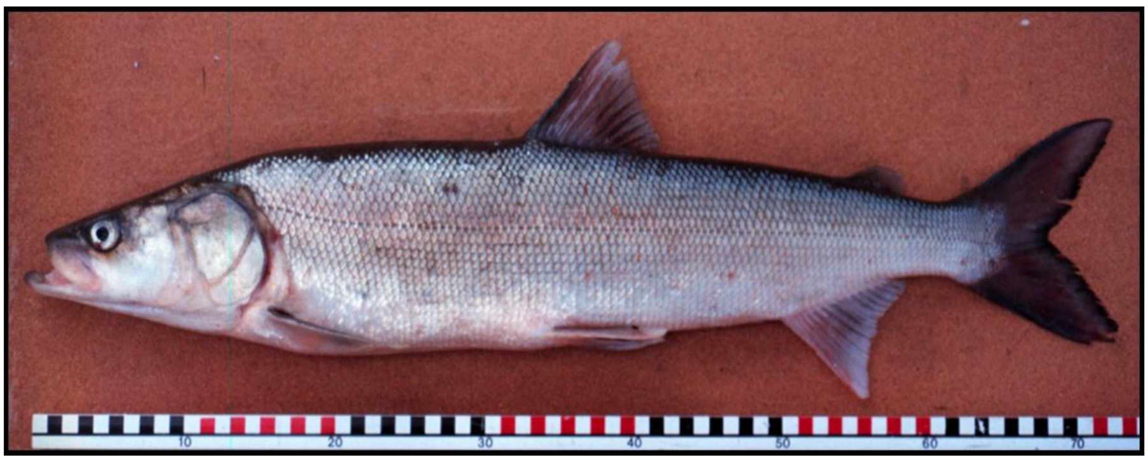

Figure 1.2. Inconnu (sheefish) *Stenodus leucichthys*; in Yup'ik *ciiq*. Ruler shows cm. (Photo by R. Brown.)

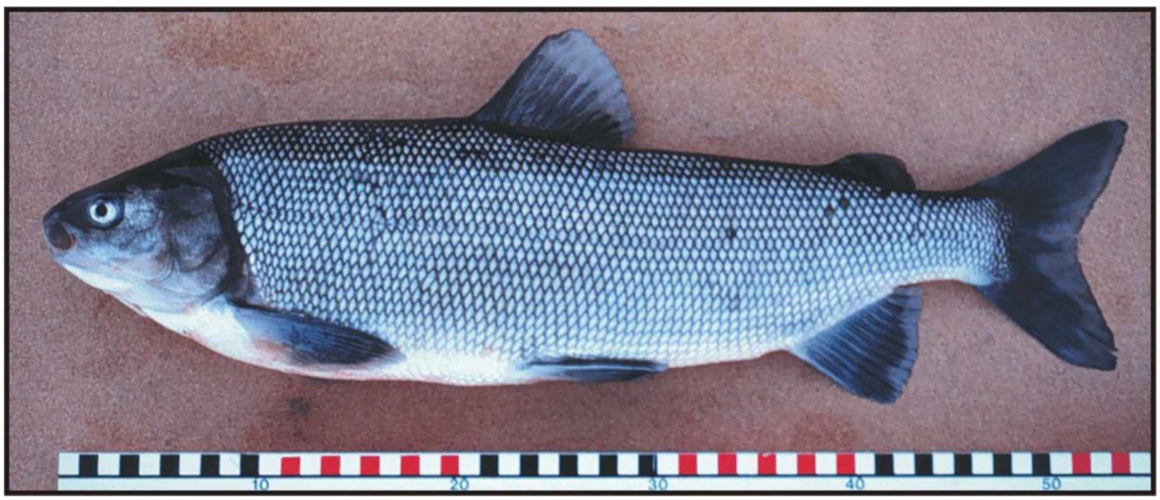

Figure 1.3. Broad whitefish *Coregonus nasus*; in Yup'ik *qaurtuq*. Also in Yup'ik large, old broad whitefish are referred to as *akakigneq*. Ruler shows cm. (Photo by R. Brown.)

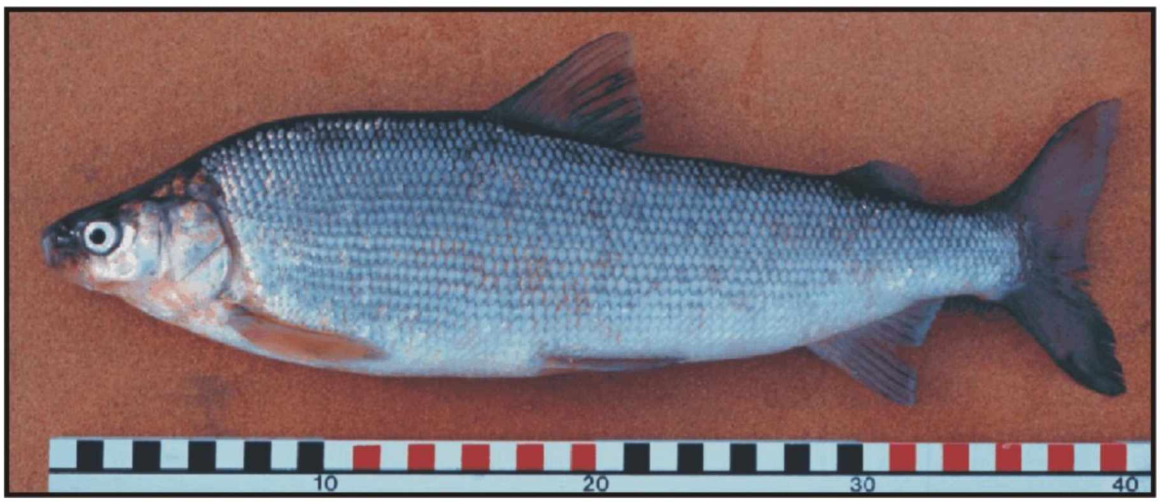

Figure 1.4. Humpback whitefish *Coregonus pidschian*; in Yup'ik *cingiikegleq*. Ruler shows cm. (Photo by R. Brown.)

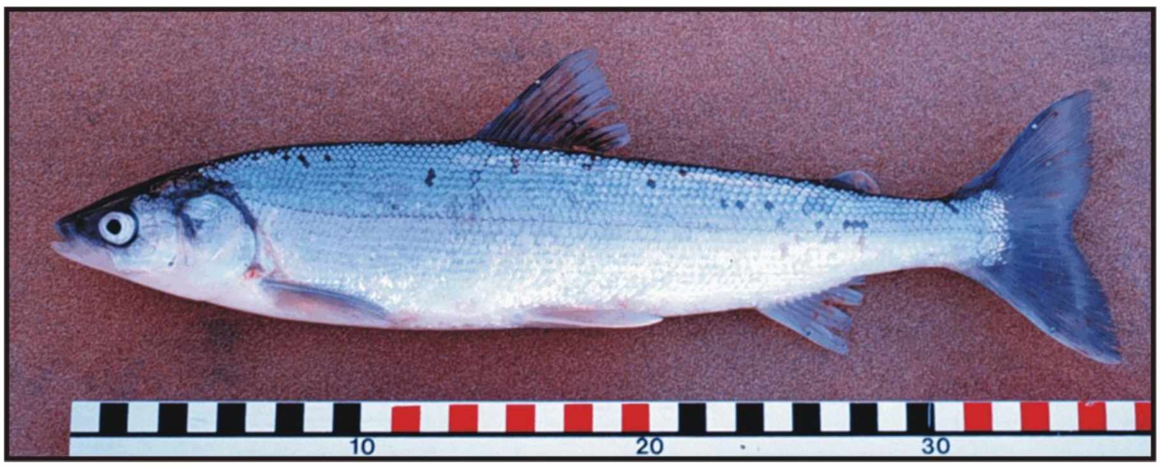

Figure 1.5. Bering cisco *Coregonus laurettae*; in Yup'ik *imarpinraq*. Also in Yup'ik *neqyagaq* when referred to as "small whitefish", or *qassaayaq* and *qassarkaq* when referred to as "small whitefish eaten raw". Ruler shows cm. (Photo by R. Brown.)

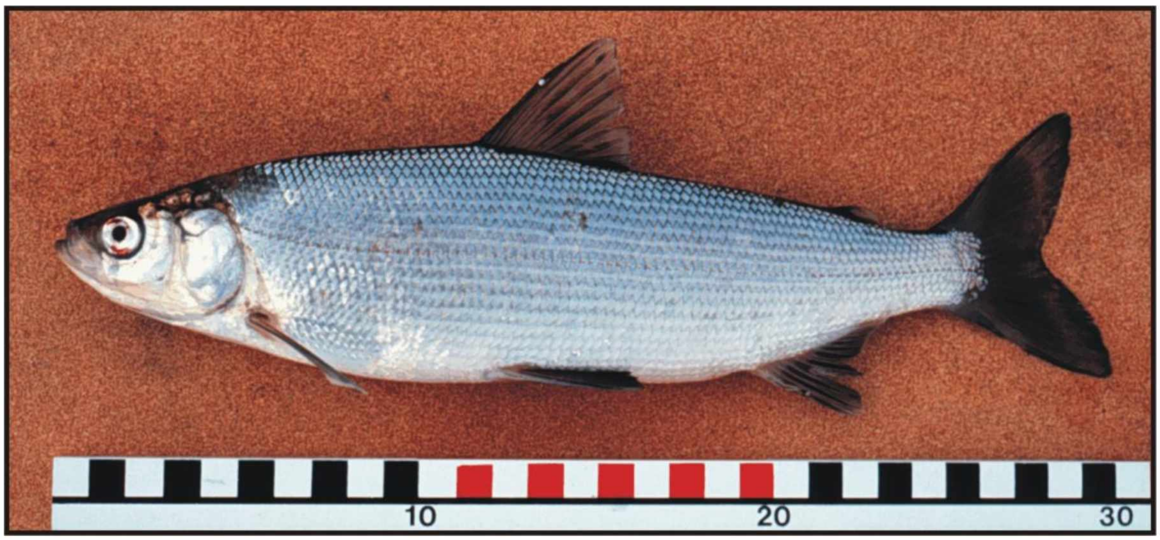

Figure 1.6. Least cisco *Coregonus sardinella*; in Yup'ik *iituliq*. Also in Yup'ik *neqyagaq* when referred to as small whitefish, or *qassaayaq* and *qassarkaq* when referred to as "small whitefish eaten raw". Ruler shows cm. (Photo by R. Brown.)

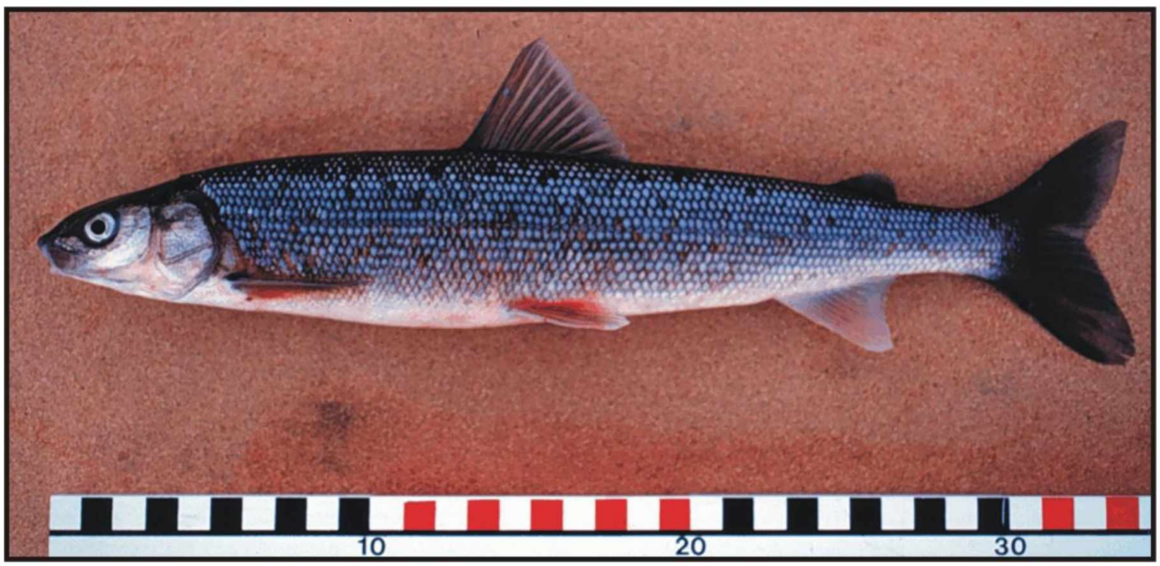

Figure 1.7. Round whitefish *Prosopium cylindraceum*; in Yup'ik *cev'eq*. Also in Yup'ik *neqyagaq* when referred to as "small whitefish", or *qassaayaq* and *qassarkaq* when referred to as "small whitefish eaten raw". Ruler shows cm. (Photo by R. Brown.)

were sometimes able to recall names for the photographs of round whitefish and least cisco, but I observed a lack of consistency in the names recalled. We harvested four of these six species during participant-observation fish harvest excursions: humpback whitefish, broad whitefish, inconnu, and Bering cisco. All participants were able to identify and name these species in the field. We did not harvest any round whitefish or least cisco in the field. Thus, we were unable to determine whether identification of these species was more definite with an actual specimen.

Although each species did have its own Yup'ik name, there were other means by which the participants identified whitefish. I observed that participants identified some whitefish by their relative size in that the smaller species are collectively referred to as small fish. Interview participants often called round whitefish, Bering cisco, and least cisco *neqyagaq* (singular) (Table 1.2) or *neqyagat* (three or more), which translates as "small fish" or "small whitefish" in context. *"Neqyaggaurut*." (Pointing to round whitefish, Bering cisco, and least cisco.) [Trans. "They are all the small fish."] (Mike Utteryuk) In addition, I observed that distinctions between larger and smaller species of whitefish are also made based upon the preferred method of consumption. Specifically, the species which comprised the group referred to as *neqyagat* were also called *qassaayaq* (singular) or *qassaayat* (three or more) which approximately translates as "small fish eaten raw". "We don't really eat the bigger ones raw even though they're the same family. We just eat the *qassaayat*." (Mary Ann Sundown) Based upon my observations of Yup'ik food preparation and consumption, one must make the distinction between consumption of raw whitefish (*qassaayat*) and consumption of uncooked, frozen whitefish (*kumlaneq*). The latter are usually prepared using humpback and broad whitefish.

During interviews conducted in English, two participants conflated the names—*neqyagat* and *qassaayat*—between both the round whitefish and the least cisco. They did not make a distinction between the two. However, they would at the same time speak specifically about one species of fish when using one of these terms. For example, one interview participant said that the "other ones we get in October when they go upstream, up freshwater streams, are the *neqyagat*, the really small whitefish." (George Smith) Review of interviews with other participants indicated that this fish of which George spoke was the round whitefish which is more specifically referred to as *cev'eq*. During an interview with Mary Ann Sundown, the eldest of the participants, the translator indicated to her that a younger interview participant had referred to the round whitefish as *iituliq* (actually the name for least cisco). Her response was the following: "That's not it. He knows this one (pointing to a photograph of least cisco) is *iituliq*. This one (pointing to a round whitefish) is *cev'eq*."

The two youngest interview participants (approximately 40 to 45 years of age) were particularly inconsistent in their identification of round whitefish and least ciscoes as distinct fish. When discussing them and using photographs as a reference, both participants contradicted older interview participants, sometimes misidentifying round whitefish as *iituliq* and least ciscoes as "small whitefish". The four older interview participants identified all whitefish with relative certainty. These individuals were decisive about their identification of these species, as well as the distinction between least cisco and round whitefish. They identified round whitefish by the name *cev'eq* and described it by its more distinctive characteristics. These included its relatively shallow body shape with a round cross section and a slightly blunt snout. They also clearly identified the least cisco as *iituliq*, distinguishing it from other species by its relatively large eyes—the Yup'ik *iituliq* literally translates as "the one with big eyes"—as well as its deeper body that is narrow in cross-section and its slightly superior mouth.

In addition to least cisco, Bering cisco also apparently possesses a Yup'ik name which is somewhat descriptive of the fish. The name *imarpinraq* is derived from a life-history trait observed in Bering cisco. The root of the name *imarpinraq* is *imarpik*, which translates "sea". All interview participants discussed the habit of Bering cisco to migrate to the ocean in winter and to remain there until just prior to break-up, at which time they return to the rivers. Peter George indicated that "as the ice gets thicker and the tide comes up…the *imarpinraq* move further down to the ocean." Francis Charlie explained the same phenomenon in greater detail. When I asked him about the origin or meaning of the name *imarpinraq* he responded, "From what I understand it is because the fish went out into the ocean in late fall and wintertime. They would all go out from the rivers into the ocean. That's why they call them *imarpinraq*."

Observed whitefish life-history characteristics and behavior

Interview participants' discussion of whitefish life history was limited to general patterns of whitefish movement and feeding behavior. All participants indicated that most whitefish tend to move through coastal streams in spring. "In springtime before the ice goes out the fish start making their way in. We used to set net under the ice to catch fish when we first went to fish camp in the spring." (Francis Charlie)

Several informants explained that later in the season these whitefish move into ponds and lakes. "In springtime around late May the fish start making their way in because the water has risen; even the sticklebacks make their way in. They go into whatever water they can sometimes by jumping from one body of water to another." (Francis Charlie)

"In June they start to come to our camp. They climb far upriver and go into small streams." (Mike Utteryuk)

"They come upriver in the spring. And the *imarpinraqs*, you go out to the bay right after the herring run and they're out there by the hundreds, really hundreds of them. Late May. They go up in the streams and feed." (George Smith)

I asked interview participants to describe what they know about whitefish feeding habits. George Smith explained that broad and humpback whitefish spend summers in ponds feeding on insects.

> For the bigger species of whitefish like the *cingiikegleqs* and *qaurtuqs* I know they eat flies. You go to the ponds and lakes or right where the sloughs go to the ponds and lakes right on the sides you'll see fish slurping up flies. I don't know what they do but I know there's fish in there eating the flies. A couple guys from here they went up and tried fly fishing and they actually caught *qaurtuqs*. (George Smith)

No other participants discussed the feeding habits of these fish, but all interview participants agreed on the feeding habits of Bering cisco. Each subject explained that Bering cisco are feeding on ninespine sticklebacks *Pungitius pungitius* and threespine sticklebacks *Gasterosteus aculeatus*—both referred to as *quaruq* in Yup'ik (Figure 1.8)—during the summer when they are found throughout the region.

> The imarpinraqs eat sticklebacks. They eat lots of small sticklebacks, and they really fill up their guts. No bugs, just sticklebacks. They are fat little sticklebacks. *Uliikutangqerluteng*. (This literally means "they have a blanket thrown over it". It was understood in this context to mean "they have a blanket thrown over their bellies.") (Mike Utteryuk)

When I asked Francis Charlie about this expression he explained that these sticklebacks are called "*qumaq*", like they have something in their pocket. "That's when the stickleback's stomach is filled with a parasitic worm."

"Things to look for is the little needlefish (sticklebacks) that you see swimming around. That's what the *imarpinraqs* feed on. If you see lots of needlefish and an occasional popping of the water that's *imarpinraqs* eating." (George Smith)

"All the *imarpinraqs* eat sticklebacks. Their stomachs are always full of sticklebacks. We catch them in the rivers and ponds. They go up there in the spring to eat sticklebacks." (Francis Charlie)

Some participants explained that in late summer and through December that whitefish move out of ponds and lakes and into the larger rivers. Mary Ann Sundown described how she and her husband, Teddy Sundown, would catch various species of

Figure 1.8. Photographs of sticklebacks. Ninespine stickleback *Pungitius pungitius* (top) and threespine stickleback *Gasterosteus aculeatus* (bottom); in Yup'ik *quaruq*, *qumaq* or *uliikutangqerluteng* when ventral surface is distended due to infestation with parasitic worms. Hash marks show one half cm.

whitefish at their camp in late summer as the fish moved out of ponds. She explained that they located their camp where a stream flowed out of a large pond containing Bering cisco and humpback whitefish. Apparently some fish will migrate out of these sites in fall during or after freeze-up. Others remain in ponds and lakes through the winter, migrating out after break-up. However, most interview participants indicated that sometime before or during freeze-up, usually from midsummer through mid- to late fall, Bering cisco will migrate out of freshwater and into the ocean.

> Around August the *imarpinraqs* come back out to the rivers and they go home to the ocean. There are lots because their young come out too…the young go out to the ocean and grow. When it starts to ice over [in ponds and rivers] there are almost none. (Mike Utteryuk)

"People usually would start catching them around late July when they start coming out from the ponds." (Francis Charlie)

"The *imarpinraqs* peak again in the fall when freeze-up starts. Early October, and we rarely get them after December. As the ice gets thicker and the tide comes up they move further down to the ocean." (Peter George)

One interview participant expressed a more complete understanding of Bering cisco life history during fall and winter. He explained that Bering cisco will travel under the ice to bays in early fall and into winter.

> In the fall *imarpinraqs* go out to the bay and sit in the deep water in a group. There is no food or very little food so they don't do anything. When the water rises they will go closer to the shore. They don't go too far in so when the water

> goes back out they can go back to the deep water. It's colder in the shallow water than in the deep water. After a [fall] flood we would suddenly catch lots. They would follow the flood. Before the ice gets thick they're still moving around. They don't come back in after the ice gets thick. The water is too low after the ice gets thick and collapses along the coast in winter. In winter when they do eat they are eating amphipods. (In Yup'ik Francis called these amphipods "*inarayuli*" which describes them literally as "lying on their side as they move".) (Francis Charlie)

Traditional and contemporary whitefish harvest practices

A significant portion of the interviews included discussions of whitefish harvest. Many interview participants indicated the importance of harvesting whitefish to the families living in the region. Traditionally, Scammon Bay families would travel to fish camps in late summer for the purpose of harvesting whitefish and remain there until after freeze-up.

> We would get in our boat and bring our kayak and cross over to Qelliq in August…and [Teddy Sundown] (Mary Ann's husband) would set a net in the slough right away. In the morning we would check the net and it would have lots of [white]fish. Later he would set a big fish trap in Qelliq. The trap was set near where the pond called Caqiqsaq flowed into the river. Here we would catch lots of [white]fish and tomcods. The [white]fish we caught were *imarpinraqs* and *cingiikegleqs*. Later on in September we would start catching blackfish along with other fish, *imarpinraqs*, *cingiikegleqs*, and sticklebacks. I would hang all

> these fish. But as it got later, when it got cold and when it started icing over we would catch mostly just blackfish…We would stay there for a long time then, after mink trapping was done…Around Christmas time we would go back to Scammon Bay. (Mary Ann Sundown)

Much of the participants' knowledge of whitefish was in reference to Bering cisco, and a great deal of the harvest information discussed referred to harvest of this species. George Smith explained that many families had their whitefish camps in the area upstream from Scammon Bay in the Kun River drainage. These camps were associated with locations where whitefish, particularly Bering cisco, were known to be abundant.

> There's certain sloughs we know of…where certain times of year they start coming up in great numbers. A place called Aparturaq upriver. The *imarpinraqs* come up in great numbers. Another slough called Ararcet'taraq. Those are the sloughs that come from bigger ponds or lakes, a series of ponds or lakes…My dad sort of had his own little spot across there at Qelliq. Pete Ulak had his own little spot in another river. And then Edward Aguchak had his own little spot further up. And the Kaganak family had their own little spot. (George Smith)

Francis Charlie was born and spent his childhood in a settlement called Anaarciq, which was on the Black River, a distributary of the Yukon River located between the communities of Scammon Bay and Nunam Iqua, Alaska. Anaarciq was a particularly desirable location partly due to the abundance of whitefish. He described his experience of traditional whitefish harvests in this area.

> The *imarpinraqs* and *iituliqs* were everywhere spread all over the place where I was born in Anaarciq. Even the young ones were mixed with the adults. There were so many that when I was young when we traveled by boat they would jump and land in the boat. That was in the fall. Even the *cingiikegleqs* and *qaurtuqs* are plentiful there when they come out of ponds in the fall. In springtime before the ice goes out the fish start making their way in. We used to set net under the ice to catch fish when we first went to fish camp in the spring. Sometimes we'd set a net right after the fish went out but the fish would be skinny. They wouldn't have any fat on them. In summer I would catch them in fresh water way up Black River near Anaarciq and up further. Even in Black River where there are little sloughs that become ponds we can catch them. Anytime in the summer. In the fall you can catch sheefish upriver. During berry season we would go into Old Black River where the mud turns to sand. It becomes a big wide river, almost a lake. I used to set net and catch big pike and sheefish. We catch *imarpinraqs* there too. In December they start going out into the ocean. (Francis Charlie)

One interview participant described how in his home community of Mountain Village, Alaska Bering cisco were traditionally harvested with nets under ice following freeze-up.

> They're common on the Yukon. The *imarpinraqs* peak in the fall time. When the weather starts getting colder. As soon as the ice gets about as thick as this table, two inches thick, set a net out you can probably get about anywhere from 100 to 200 pounds of *imarpinraqs*. (Peter George)

When I asked him to describe how Bering cisco were harvested in the Yukon River near Mountain Village, he explained that they would also use large fish traps lowered under the ice. These traps were made of split white spruce poles and chicken wire. They are still currently in use in some lower Yukon River communities. Francis Charlie also described catching whitefish under the ice in the past.

> I caught so many of them once with Roy Henry that I caught a sled load and filled many gunny sacks. We almost gave up because there were so many fish. We caught *imarpinraqs*, *cingiikegleqs*, *qaurtuqs*, and *iituliqs*. This was in Black River at our fish camp. We also caught pike and burbot along with the [white]fish. This was around early December under the ice. (Francis Charlie)

As mentioned above, during every interview the majority of discussion focused on Bering cisco. This was the species that interview participants knew most about. Participants considered Bering cisco to be the species of whitefish with the highest quality of taste and nutrition. All interview participants expressed that this is due to the high oil content of Bering cisco flesh. They are also harvested early in spring when they are thin and lack much oil. At this time of year and in this condition, filleted Bering ciscoes dry quickly. Francis Charlie's comments on this phenomenon are above. George Smith also discussed the existence of thin or wasted Bering cisco in spring.

> The *imarpinraqs*, you go out to the bays right after the herring run and they're out there by the hundreds, really hundreds of them. Late May. They're very skinny then. They don't have much meat on them. So we just leave them alone and they

> go up in the ponds and feed. We catch them mainly in the fall, August through November. Berry season until freeze-up. (George Smith)

When I asked him why the Bering cisco was such a desirable species of whitefish, he explained that they have the best taste due to the high oil content.

> The *imarpinraqs* are the most popular ones because they're the tastiest. They have a really oily taste; rich, oily taste. There's the other species [of whitefish], even though you boil them they sort of taste dry. It doesn't have that high oil content. (George Smith)

Interview participants also discussed harvests of other whitefish species. Two individuals discussed harvests of broad whitefish. Both persons formerly resided on or near the Yukon River where this species seems to be more abundant.

> Some of the broad whitefish get really big. They can grow almost as big as Chinook salmon. There are some that stay way in the big ponds. When the water rises high enough and it fills the inland they will roll out of the ponds and go into the Yukon and Black Rivers. We call those big, old *qaurtuqs* "*akakigneq*". (Francis Charlie)

Peter George also discussed harvest of broad whitefish.

> These (pointing to a photo of broad whitefish) you can get on the other side [of Scammon Bay mountain] or here, but very few. But if you go anywhere in Black River you can get a whole bunch. The biggest ones I ever seen and caught were further up Black River where it gets right across from Mountain Village. Where you can jump the river they get to almost two and a half almost three feet in

> length. They go in the lakes and out of the lakes. They stay in the lakes in the winter and towards spring they go back out into Black River. They're going out towards the spring, towards summer you hardly get them in Black River. And then they pick up again as winter approaches they move back upriver. (Peter George)

One historical harvest of particular interest was that of least cisco, which are no longer abundantly harvested in the region. Peter George expressed his opinion that they were still present but not as common as in the past.

> The least cisco, *qassarkaq* (variant of *qassaayaq*), you can get them now until about December…Most of our fishing we do on the other side of Scammon here, along Kokechik [Bay]. We go over the pass by Castle Rock and once you get down to the rivers you can just about set anywhere you want…Within these past ten years on the other side of here they've been gradually declining. You set two or three nets you don't get as many. You might get fifteen. Before that if you have one net out overnight you get about, I'd say, 60 average. Now if you set two nets out you'll probably get maybe 30. (Peter George)

Mike Utteryuk and George Smith each expressed similar observations.

> We used to catch lots of *iituliqs* in the streams on the other side of the mountains. They would be in the streams; from the mouth all the way up to the very end. We used to catch lots of them in the stream below Castle Rock. Now there are nothing, even the burbot. Now we never see any. (Mike Utteryuk)

> These (pointing to a photo of least cisco) we get in October when they go upstream, up freshwater streams, is the *neqyagaq*, the really small whitefish. They used to travel up the streams by the hundreds of thousands. We'd herd them into a dip net and pull them out. We'd bury them underground. Hope and pray that the fox don't get to them before we do. Yeah, they're small. They used to be very prized, sort of a delicacy. They used to get them by the 50-pound sack. We don't catch them anymore. They don't come up anymore, along with the lush fish (burbot). (George Smith)

Apparent effects of increasing beaver population on whitefish

All interview participants discussed their observations of an increase in beaver population throughout the region of Scammon Bay and many areas of the Yukon River delta. They related the higher abundance of beavers and their activity to changes in fish abundance. They explained that beaver dams create a barrier to fish passage in feeding streams throughout the area.

> We used to catch *iituliqs* before the beavers started to be abundant. They block the stream so they cannot get into the stream…Now we never see any. There used to be lots of sloughs but now they're blocked off by beaver dams. Now there are ponds. (Mike Utteryuk)

"It's those goddamn beavers putting dams all over…They're blocking their streams." (George Smith)

> Beavers have blocked the places where the fish go. Even the blackfish have had trouble spawning because of their spawning places being blocked by beaver dams.

> We even see king salmon and chum salmon blocked by beaver dams. One time we went inside the river near Scammon Bay and there was a beaver dam that was about four feet higher than our boat. It blocked many [white]fish in the river. They were stuck and couldn't get out. This was when we were out moose hunting and picking berries. The coho salmon and chum salmon were blocked, swimming in front of the dam trying to get in. (Francis Charlie)

> You go anywhere here along the coast, walk alongside the mountains you'll come across beaver dams. I mean they're all over. You'd see streams years ago it never dawned on you that there'd be a beaver dam. And now there is. Little trickling streams become reservoirs… You can find [beavers] right along the ocean. We camp out there and every year for the past five years, ten years there'd be a beaver swimming out on the beach in the ocean. I never thought I'd see a beaver swimming out there. Out of curiosity—we have a couple small streams out there—I went up to find out what it's like. Little tiny trickling streams that you can walk over you come across huge beaver dams. There'd be two or three of them. It's the reason why on the other side we're hardly getting any fish, even in ponds and lakes all over. (Peter George)

In recent years, residents of this region have perceived an increase in beaver population on the Yukon River delta beyond the tree line. Interview participants believed that, until approximately 20 years ago, beavers were limited to more heavily forested areas upriver from the delta proper and that they were present but relatively rare on the tundra. Peter George offered a widely accepted explanation for the perceived increase in beaver population, relating it to trapping.

> People no longer trap them. Now they're just literally all over the place… My dad and the older generation trapped them for a living. Fur bearing animals, they'd maintain the population, keep them in check. You'd trap them certain time of the year, you'd start in October trapping them up until December and you quit trapping after that. Then again in the spring time when days are getting longer and break-up's starting up, you trap them again, trap or hunt them. Very few people trap them anymore, very few. Right now fur bearing animals are not worth trapping anymore. Thirty years ago, twenty, the average income for people on the Yukon, Mountain Village, average income within two months we'd get about $7,000 just out of fur bearing animals muskrats, beaver, otter, fox, mink. Those five animals. Basically October, November, December you're trapping. That's a source of income for your family. Now it's not worth trapping anymore unless you just want to wear them for parka, mittens, wall decoration. (Peter George)

Discussion

I have chosen to organize the interview results of this study into four categories: Yup'ik whitefish nomenclature, observed whitefish life-history characteristics and behavior, traditional and contemporary whitefish harvest practices, and discussion of an apparent increase in beaver population on the Yukon River delta. These categories are artificial and of my own design, but based on themes which emerged during my review of interview recordings. It is important to note this because I conducted each interview in a manner in which the interview participants were encouraged to discuss topics of their choice. My prepared questions guided them at times. Questions usually arose from interesting points of discussion which the participants broached themselves. Thus, one should not infer from the reading of these results that interview participants chose any such organization or structure to their knowledge of whitefish.

Rather, each individual expressed a holistic understanding of whitefish, particularly as they relate to Yup'ik lifestyles, both traditional and contemporary. Mary Ann Sundown offers a unique example of this approach to sharing knowledge of whitefish. At the age of 85, Mary Ann was the eldest interview participant in this project. Perhaps half of her life experience had been during a time when daily activities were very similar to those of an era prior to Euro-American contact. When I began my interview with Mary Ann, she did not solely discuss whitefish. Instead, she told of the cycle of seasons that she experienced each year, beginning with her family's travel to spring camp to harvest whitefish. She narrated the cycle of travel and harvest that defined the Yup'ik way of life. The manner in which she chose to express her knowledge of whitefish was to share every aspect of this way of life. Whitefish were merely part of a larger cycle. Families moved between camps as their sources of food moved or changed. In this way, whitefish possibly represented one of the aspects of life upon which Yup'ik tradition relied: fish. Fish provided stability for the Yup'ik family, and as such, Yup'ik seasonal cycles followed the sources of fish. Following sources of fish required that Mary Ann and her contemporaries acquire extensive knowledge of fish life history. Descriptions of fish life history should not, to her, be separated from her own life history.

For a western scientist to interview a traditional Yup'ik person like Mary Ann, he or she must accept that her view of the subject may not be discretely defined. As such, it is impossible and unnecessary to utilize her or another person's experience in a way that attempts to complete a catalog of knowledge on a subject (Cruikshank 1998). Instead, a fisheries biologist may need to allow the interview participants to guide any project of this type. To do so requires that the scientist not look for a problem to solve or a question to answer with the assistance of experienced subsistence fishers. The problems and questions will arise from the interview and participant observation processes.

To facilitate a successful project like this, a researcher must develop long-term relationships with communities of interest before beginning. I was fortunate to be able to develop a project after many years spent living on the Yukon River delta, including in Scammon Bay. My ties to the community are through marriage, and as such, I have lived closely with Yup'ik subsistence fishers for many years. I came into the project with a desire to learn about the life history of whitefish and their role in Yup'ik subsistence traditions. From interviews, participant observations, and scientific research, I did discover a number of Bering cisco life-history traits that are only poorly understood by fisheries scientists (see Chapter 2).

There was another benefit I received from my previous experience in Scammon Bay, which was my familiarity with Yup'ik styles of communication. I was aware of the need to conduct interviews at a pace comfortable for the participants. Typically, my own comfortable pace in a conversation is much faster than that which is comfortable for a Yup'ik person, particularly elders. I observed that interview participants would usually pause for several seconds before responding to a question, or pause during their statements. I asked my interpreters, a Yup'ik woman, what was her understanding of the significance of these pauses. She believed that a pause gives a person time to think about what they wish to say. In some contexts, a pause can also be a polite way for a person to wait for the speaker to finish what he or she has to say before responding. This politeness is an example of the practice of deference in Yup'ik conversation and other social interactions (Oleksa 2005). It was essential that I remain aware of this practice during my interviews. I could not give interview participants the impression that I was motivated by a schedule or that the purpose of an interview was to result in a discrete product (e.g., specific whitefish data, a transcript, a list of locations where whitefish are harvested). If I had given this impression or appeared to be rushing or forcing a response, the result could have been the end of an interview or even the failure of the project.

Despite my cultural awareness, I did experience some problems in the interview process. Beginning this project, I was an inexperienced interviewer. Conducting traditional knowledge interviews with people from outside my cultural and language background presented many challenges. I did occasionally find myself inadvertently leading some interview participants, or suggesting possible correct responses. This often occurred when I asked questions in a way that suggested I might be expecting a particular response. My interpreter later explained that I sometimes gave the impression that I desired to hear a certain answer. Because traditional Yup'ik people are often deferential in their social interactions, they may have felt that it would be impolite to disappoint me with an answer I did not want. To them, the socially acceptable and proper choice was to tell me what I apparently wanted to hear.

This came out when I asked participants whether Bering cisco were spawning in the area. I asked this question because I had heard traditional knowledge accounts of whitefish doing so, despite the fact that the Yukon River delta lacks the substrate that whitefish require for spawning. Many of the interview participants responded positively to this question. Upon correction from my interpreter, I chose another approach. I showed the same individuals a photograph of a gravid female Bering cisco, with fully developed ovaries excised and exposed, collected by a fish biologist working in a known Bering cisco spawning site (Figure B-2). I then asked if they had ever seen a fish like the one in the photograph. Each of them responded negatively. From this experience, I would conclude that the latter responses were probably accurate, and the former were likely influenced either by my tone during the interview or by the participants' customs of communication.

It was also essential to apply the professional standards of ethnographic research to this project. Traditional knowledge and other oral history studies have standard basic criteria by which to evaluate interviews. Two of the criteria are internal—consistency and reasonableness. First, the consistency criterion determines whether there are any contradictions within a participant's interview statements. Second, the reasonability criterion tests whether statements are logical and well reasoned. The third is the external criterion of comparability. In this latter test, the researcher determines similarities or discrepancies among different participants' statements (Schneider 2002). If a participant's statements fail to meet any of these criteria, the researcher must determine the source of the failure. It may be the result of misunderstanding or miscommunication, in which case the researcher must reinvestigate the query. If this fails to resolve the discrepancy, then a researcher must compare the interviews with observed biological data taken in the field.

I did have to apply these standards to my review of the interview results. I found one inconsistency when an interview participant seemed to claim that least ciscoes were both abundant and rare near Scammon Bay. When I inquired as to this inconsistency we discovered that he was speaking in present tense when he described their abundance, when he actually intended to be speaking in past tense. He intended to describe the historical information about least cisco as being an abundant fish. The reason for his confusion we concluded was that he is a native Yup'ik speaker and was speaking to me in English, simply making a grammatical error. So my check on the inconsistency resolved any questions about his statement.

A more common example of the challenge of consistency is in the variability of interview participants' names for whitefish. I use the term *nomenclature* herein because when discussing whitefish, participants expressed a system of names for the six species found within the study region. Other authors have used the term *taxonomy* (Georgette and Shiedt 2005) to describe the manner in which Alaska Native groups name or possibly classify different fish. I favored the use of *nomenclature* over *taxonomy* because participants discussed names of fish, not a system or systems of classification of fish species or other groups. One interview participant, Mary Ann Sundown, recognized whitefish as a group of related fishes when she looked at a photograph of the six species of whitefish known to inhabit the Yukon River drainage. At the time, she was discussing consumption of whitefish and referred to the group as the same family when she said, "We don't really eat the bigger ones raw even though they're the same family. We just eat the little ones raw." This was the only mention of an inherent relationship among all species of whitefish. There was no term used to describe all whitefish species as a distinct group or taxon. When speaking of whitefish in Yup'ik, participants would use the word "*neqet*" which translates "fish" (three or more). Each individual type of fish had a common name. These common names were not always limited to species as defined by Western science. In some contexts, the Yup'ik name (e.g., *imarpinraq*) defines the same fish that the scientific name (e.g., *Coregonus laurettae*) defines. In other contexts, the name describes some quality of the fish which is not defined by the scientific name (e.g. *qassaayaq*, small fish eaten raw; *neqyagaq*, small fish).

Discussing names of fish can be confusing in a study involving more than one Yup'ik community. This is due in part to the numerous Yup'ik dialects found throughout the Yukon River delta. Even within Scammon Bay there are several dialects spoken. Francis Charlie from Anaarciq speaks one dialect, Peter George from Mountain Village speaks another, and the remaining participants speak the dialect most common in Scammon Bay. Given their long experience in Scammon Bay, both Francis and Peter were able share names from distinct dialects when necessary.

I found that it was essential for me to learn all the Yup'ik names for all fish. All interview participants knew the whitefish only by their Yup'ik names. Sheefish was the only English common name for a species of whitefish that all interview participants knew. This may be due to the fact that the English name commonly used in Alaska (i.e. "sheefish") is likely derived from the Yup'ik name, *ciiq*. However, no one could identify any fish by the names humpback whitefish, broad whitefish, Bering cisco, least cisco, or round whitefish. Thus, calling whitefish by their English common names during interviews would have been futile.

In this study I do not develop a standardized record of names for Yup'ik whitefish such as Georgette and Shiedt (2005) have done in the Kotzebue Sound region of Alaska. As mentioned above, fish names discussed with participants are common to the few Yup'ik dialects spoken in Scammon Bay, and may be uncommon in or unknown to speakers of other dialects in the region. It would require a study of much larger scale to define and record Yup'ik names for all species of whitefish throughout southwestern Alaska. Also if such a study ever occurs, it would be essential to utilize the Yup'ik University orthography (Miyaoka and Mather 1979) in recording the names and other related terms. I have attempted to do so here because it is currently the standard orthography in use in Alaska. Past documents recording Yup'ik names for whitefish and other species have not uniformly used the University orthography. This can result in some confusion when researching whitefish traditional knowledge (e.g., Wolfe 1981; Stickney 1984). Instances where I have not used the University orthography include place names published in maps, (e.g. "Tungpuk").

Interpretation was another concern which I needed to consider while reviewing interview responses. There are three aspects of interpretation which I will briefly address here: interpretation of language by the interviewer and by the interviewee, interpretation of participants' experiences and observations, and my own interpretation of the cultural significance of some responses. Language interpretation—not limited merely to translation of language but inclusive of understanding context and meaning of words—was occasionally challenging. The most remarkable example was again my use of the word "spawning". Not only was it apparent that participants responded positively when I asked about spawning whitefish, but also I later discovered that individuals did not define the term as I had. To a fisheries biologist, the term "spawning" refers to the discrete biological act of fish reproduction. After discussion with my interpreter and an oral historian, we determined that it was possible the participants and I did not agree on the definition of spawning. Through further discussions with participants, I later discovered that the term "spawning" was commonly understood to mean migration of a group of fish and not a reference to fish reproduction. Interview participants may have understood that some fish migrate in order to reproduce, but they did not necessarily relate spawning with reproduction within the context of the interview.

This alone should have remarkable significance to fisheries biologists and other fish resource managers in Alaska and elsewhere. Many Alaska Native groups confer often with biologists and managers. These dialogues may be in informal situations such as during interactions at field research sites or unrecorded conversations about fish. They may also occur in more formal settings such as recorded interviews like my own, meetings with village traditional councils, or Alaska Board of Fisheries and U.S. Federal Subsistence Board meetings. It is important for resource users, biologists, managers, and other interested stakeholders to review their terminology before discussing it. They may discover nuances or even misunderstandings of language similar to those reviewed here.

A second issue regarding interpretation is the need to avoid interpreting interview participants' experiences and observations. One of the more interesting topics discussed in interviews was each person's description and concern over the observed increase in beaver population throughout the study region. Although I did not investigate this phenomenon in my fieldwork, I believe it is necessary to review the issue here briefly. Participants all independently noted that more beavers were present in their region as compared to 20 or 30 years earlier. All related this phenomenon to the decline of trapping by local resource users. They explained that the decline in trapping was the result of lower fur prices. According to participants, at present, it is not economically feasible for trappers to harvest beavers. They also reasonably correlated the increase in beaver population to an increase in beaver dams. Their conclusion is that increase in beaver population and resulting increase in dams create habitat which hampers fish passage. A number of participants also made the connection between observed increases in the number of beaver dams with observed decreases in least cisco populations. When speaking of the increase in beavers, participants were relating their awareness of an important relationship between humans and the natural environment. They expressed concern that beavers may be affecting fish passage in streams, as well as disappointment over changes in Yup'ik lifestyles. Yup'ik subsistence activities had changed so much that people's behavior was beginning to alter the environment.

As an ethnographer it is essential to avoid interpreting participants' reflections on beaver-fish interactions. One could say that this is likely not as straightforward an issue as it may seem to the participants. The effect of beaver dams on fish may not be intuitive. Beaver dams can hamper fish passage (Gard 1961) and they may also provide cover and preferred feeding habitat for juvenile fish (Collen and Gibson 2001). It may be of interest to future fish and wildlife researchers to investigate the extent of these phenomena within the study region. This topic has been discussed and investigated by others in the past both within the Yukon River delta (Nelson 1918), elsewhere within the Yukon River drainage (L. DeWilde, Yukon River Intertribal Watershed Council, personal communication; A. von Finster, Department of Fisheries and Oceans Canada, personal communication), and in other North American systems (Gard 1961; Svejcar 1997). It also may be reasonable to consider the possible relationship between increases in beaver populations with changes in vegetation in northern Alaska and on the Yukon River delta (Tape et al. 2006) as an effect of climate change in Alaska.

Using only Western scientific methods of inquiry to explain changes in beaver populations or other natural phenomena, reduces observations to quantifiable biotic and abiotic factors. Yup'ik interview participants expressed direct connections between beaver populations and human behavior. Their holistic interpretation recognized that the complexity of natural systems included dimensions of human mores, culture, and spirituality. The Yup'ik way of knowing links humans, beavers, fish and other natural agents. This indicates that Western scientists and resource managers should remain open to Yup'ik and other indigenous modes of interpretation. Indigenous communities may desire to include traditional cultural values as components of comprehensive resource management plans. My study reinforces the value of research and management efforts that are inclusive of these needs, and recommends awareness and communication among these groups.

Finally, it was essential that I avoid any cultural interpretation of interview responses. I believe it is important to infer from some participants that traditional and contemporary harvests of whitefish were an integral part of the Yup'ik way of life and a determining factor in seasonal movements of families between fishing camps. Bering cisco clearly held prominence among all whitefish due to the high quality of the fish as food. They are highly desirable relative to many other species of fish. When I asked George Smith which of the fish was most prized he claimed that Bering cisco were the "best fish." When I asked him to clarify whether he meant they were the best of the whitefish, he responded that they were as good as Chinook salmon, and perhaps even better because people can catch them for longer periods of time. The presence of whitefish throughout the year made their value comparable to Pacific salmon. Just as Pacific salmon were essential to interview participants as a high quality food source found in great abundance for a few months, so were whitefish essential in that they were a reliable food source even when Pacific salmon were scarce or absent.

Interview participants expressed concern about changes in the harvest of whitefish and the apparent loss of traditional knowledge and skills among residents of Scammon

Bay. George Smith shared his concern that there were very few young people continuing traditions of subsistence activities of any kind.

> I know for myself, we go until we can't go any more. We just go out and get, and there's not very many families that do it as much as before. There's a lot of people who go to the store and buy a box of…fried chicken or fish sticks. There are not as many families that go out and, you know, harvest the fish and store them like they used to 20 years ago. It was very common back during my dad's time. (George Smith)

Francis Charlie noted that this phenomenon has resulted in the fulfillment of a traditional prophecy. He related a story to explain why natural cycles seem to be changing. The story predicted that people's loss of traditional values and their desire to "go faster" would cause Earth to turn faster, bringing about natural and human turmoil. As a result weather is warmer, there are more storms, and animals change their habits. From Francis' point of view, many people have lost awareness of traditional values, and have become dependent on non-traditional ways. This, in turn, causes animals to avoid people, and the weather behaves like humans by becoming careless and destructive. Francis' words were, "*Ellam maligluta*": the weather mimics us. The implied remedy for this is that young people should learn and practice traditional Yup'ik values. One method of doing so may be to engage elders and youth in discussions and activities regarding subsistence traditions, and recording these events for future reference. A study such as this gives Alaska Natives an opportunity to discuss their lives as traditional fishers, hunters, and gatherers free of any scientific interpretation. Talking with people about traditional ways, recording interviews, and giving these recordings to participants allow community members to share their understanding of the natural world where they make their livelihood. Elders can impart their knowledge and experience to young people, as well as offer their own reflections on issues of cultural and social significance in their communities.

Chapter 2: Description of Bering cisco *Coregonus laurettae* stock characteristics, diet, and gill rakers in the coastal Yukon River delta

Introduction

Healthy whitefish (subfamily Coregoninae) populations are increasingly recognized as key components of aquatic ecosystems (Reist and Bond 1988; Tallman et al. 2002; Amundsen et al. 2003; Harper et al. 2007) and subsistence economies (Treble and Reist 1997; Berkes 1999; VanGerwen-Toyne 2002; Georgette and Shiedt 2005) in Arctic and subarctic regions. In spite of their importance to biological and human systems, it is apparent that whitefish are poorly understood. While there is considerable published research on whitefish throughout North America and Europe, the biology and life histories of Alaska's whitefishes remain largely unknown (Reist 1997; Brown 2004). As a result, there is a clear need to investigate fundamental life-history characteristics such as larval and juvenile development, feeding ecology, migration and spawning patterns, and spawning habitat conditions and locations for many whitefish species in Alaska.

Whitefishes in general are known to possess complex life histories, exhibiting variations in migratory behaviors within species (Reist and Bond 1988; Tallman et al. 2002). Many whitefish species in Alaska consist of both resident and anadromous populations (Brown et al. 2007; Harper et al. 2007) throughout their geographic distribution. Within Alaska, only Bering cisco *Coregonus laurettae* and Arctic cisco *C. autumnalis* are strictly anadromous in their life histories (McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980; Mecklenburg et al. 2002). Bering cisco, the focus of my study, is prevalent in Alaskan coastal marine habitats. It was first described by Bean (1881), but only recently distinguished from *C. autumnalis* by McPhail (1966) and Bickham et al. (1997). The distribution of Bering cisco is from the western Beaufort Sea in the Arctic, throughout the eastern Chukchi and Bering Sea coasts to Bristol Bay, and from the Alaska Peninsula to Cook Inlet (McPhail and Lindsey 1970; Scott and Crossman 1973; Blackburn et al. 1979; Morrow 1980). Although Bering cisco is known to be primarily an Alaskan species, they have also been observed in Russia in the Chegitun River on the Chukchi Peninsula (Chereshnev 1984).

Mature Bering ciscoes undergo long spawning migrations in the Yukon and Kuskokwim rivers (Alt 1973a; Morrow 1980; Bickham et al. 1997) and the Susitna River (ADFG 1981). Spawning migrations from coastal marine areas begin in late summer, and spawning likely takes place beginning in late September through mid October (Alt 1973a). Alt (1972; 1973b) observed spawning migrations of Bering cisco occurring in late summer in the South Fork of the Kuskokwim River and in late September in the Yukon River upstream of the Porcupine River. Brown (2000) also observed Bering cisco in late September in the same area of the Yukon River, approximately 1,630 to 1,740 river kilometers (rkm) from the Bering Sea. These individuals were described as exhibiting characteristics of spawning readiness, freely expressing milt and eggs when handled (Brown 2000). In the Susitna River, Bering ciscoes were observed spawning during the second week of October from rkm 120 to 129 (ADFG 1981). Spawning adults form aggregations in the main river channel and broadcast spawn over gravel ranging from 2.5 to 7.6 cm in diameter (ADFG 1981). After spawning, it is believed that adults overwinter in rivers or migrate downstream to estuarine habitats (McPhail and Lindsey 1970; Alt 1973b). Larvae drift downstream after emerging from spawning substrates (Naesje et al. 1986; Martin et al. 1987; Shestakov 1991), and are reared in coastal marine and estuarine habitats where juveniles feed on invertebrates and cottids (McPhail and Lindsey 1970; Alt 1973b; Morrow 1980).

Bering cisco are found in great abundance both in coastal marine habitats (McPhail and Lindsey 1970; Alt 1973b; ADFG 1981; Morrow 1980; Georgette and Shiedt 2005) and in the Yukon, Kuskokwim, and Susitna rivers during spawning migrations (Alt 1972; Alt 1973b; Alt 1974; ADFG 1981; R. Brown, U.S. Fish and Wildlife Service [USFWS], unpublished data). Population estimates have not been determined definitively with field studies. However, in a study of whitefishes in the Yukon River from 2001 to 2008, relative abundance data indicated that Bering cisco outnumbered all other whitefish species combined (R. J. Brown, USFWS, unpublished data). Juvenile Bering cisco in coastal marine habitats has supported traditional subsistence harvests and, as such, it comprises a large portion of the diets of many rural Alaskans (Stickney 1984; Georgette and Shiedt 2005; LaVine et al. 2007). In addition to traditional harvest by rural Alaska fishers, Bering cisco is also exploited commercially in the Yukon River delta (Fabricant 2008), despite limited data to support management of this fishery.

To develop proper management strategies for Bering cisco, scientists must expand their investigation of the biology and life-history characteristics of this species. This study attempts to extend background scientific knowledge of Bering cisco, with the expectation that it will assist future researchers in continuing investigations into this poorly understood species. There are several fundamental areas of inquiry that may help to guide research on Bering cisco. First, it is essential that scientists describe basic stock-assessment characteristics of juveniles in coastal marine habitats to allow prediction of abundance for the purpose of managing commercial and subsistence fisheries. Second, it is important to record any morphological traits which may lead to identification of the three Bering cisco spawning stocks. Finally, observations of prey selection in productive rearing habitats will inform researchers of the relationship between Bering cisco feeding ecology and anadromy and amphidromy as an adaptive strategy.

The goal of this study is to describe several phenomena which will advance our understanding of Bering cisco life history. I estimated age of Bering cisco specimens and described age-frequency distribution and length at age to record baseline year-class data for Bering cisco in the Yukon River delta. I conducted a diet analysis to describe the feeding habits of immature Bering cisco. These data can potentially be applied to future studies investigating ecological, life-history, and stock-assessment characteristics of Alaska's Bering cisco populations. To verify an important morphological characteristic of Bering cisco as a species, I compared gill raker count data from my specimens with those of previous studies (McPhail 1966; Bickham et al. 1997).

Methods

Study area

The study area is located on the Yukon River delta, a region that is approximately 98,000 km^2 and extends into the Bering Sea (Figure 1.1). It is a subarctic, coastal plain, which consists of lakes and meandering, low-gradient streams with high silt load from upstream erosion. The delta is a mix of marsh, tidal flats, and tundra, and approximately 30 to 50% of the delta is lake surface (Brabets et al. 2000). Study sites for this project were in the Kun River drainage, which flows into the Bering Sea at Scammon Bay, Alaska (61.843°N, 165.581°W) and the Black River, a distributary of the Yukon River that flows into the Bering Sea near the seasonal fish camp community of Black (62.336°N, 165.339°W) (Figure 1.1). Tidal zones extend many kilometers inland from the coast transporting marine nutrients throughout the system, and significantly affecting vertebrate and invertebrate communities.

Aquatic habitats within the study region include coastal marine, brackish, and freshwater regimes. Resident fish species include Alaska blackfish *Dallia pectoralis*, burbot *Lota lota*, Arctic cod *Boreogadus saida*, Pacific cod *Gadus macrocephalus*, Pacific tomcod *Microgadus proximus*, saffron cod *Eleginus gracilis*, six coregonid species (Bering cisco, broad whitefish *Coregonus nasus*, humpback whitefish *C. pidschian*, inconnu *Stenodus leucichthys*, least cisco *C. sardinella*, round whitefish *Prosopium cylindraceum*), Dolly Varden char *Salvelinus malma*, belligerent sculpin *Megalocottus platycephalus*, Bering poacher *Occella dodecaedron*, fourhorn sculpin *Myoxocephalus quadricornis*, Arctic flounder *Liopsetta glacialis*, starry flounder *Platichthys stellatus*, northern pike *Esox lucius*, pond smelt *Hypomesus olidus*, rainbow smelt *Osmerus mordax*, ninespine stickleback *Pungitius pungitius*, and threespine stickleback *Gasterosteus aculeatus*. Fish species which move into or through the region during spawning migrations include Arctic lamprey *Lampetra camtschatica*, Pacific herring *Clupea pallasii*, and four Pacific salmon species (Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, and pink salmon *O. gorbuscha*).

Biological sampling

Biological sampling procedures were reviewed and approved by University of Alaska Fairbanks Institutional Animal Care and Use Committee (UAF IACUC Protocol number 04-23; Appendix C) and Alaska Department of Fish and Game, Sport Fish Division (ADFG Fish Resource Permits SF-2005-150 and SF-2006-186). In August 2005 and August 2006, I collected Bering cisco at three sites on the Black River within 2 river km of the river mouth and 15 sites on the Kun, Kikneak, and Tungpuk rivers within 22 river km of Scammon Bay. Sampling occurred in August due to practical and logistical concerns of local subsistence fishers, whose vessels were my means of transport to sampling sites. Sampling sites included slough mouths and river channels. At each site, I measured salinity (practical salinity units [PSU]) at a depth of 30 cm using a Goldberg® hand-held refractometer (Leica Incorporated, Buffalo, New York). I deployed a monofilament mesh gill net (9.1 m long x 1.83 m deep; 38-mm bar mesh) at each Black River site and at 13 of the 15 Kun River sites. I deployed a monofilament multi-panel gill net (43.92 m long x 2.44 m deep; six 7.32-m panels of 9.5, 12.7, 19, 38, 47.6, and 66.7-mm bar mesh) at the remaining two Kun River sites. Nets were deployed for 30 minutes before removing them from the water and collecting fish. I estimated catch-per-unit-effort (CPUE) by calculating the mean number of fish captured per net hour. I based the CPUE estimate on catch data from the 38-mm mesh nets.

I retained all Bering cisco for sampling purposes. Any other species of fish were either released or donated to residents of Scammon Bay. At each site, I also collected ninespine sticklebacks and threespine sticklebacks using a nylon-mesh pole seine (2.44 m long x 1.22 m deep; 6.4-mm stretch mesh). All sticklebacks were released following capture. I recorded the weight of all Bering ciscoes to the nearest 1 g using a spring balance. Age-0 Bering cisco were too small to register on a spring balance, so weights for these fish were recorded to the nearest 0.01 g using a microbalance. I recorded the fork length (FL) for all Bering ciscoes to the nearest 1 mm. Except for age-0 fish, I attempted to identify the sex of each Bering cisco by observing ovaries or testes.

To access otoliths, I made a transverse incision from the dorsal surface of the supraoccipital bones into the brain case. I then made a lateral incision, from left to right, beneath the epiotic and parietal bones. This created a door of tissue which opened anteriorly to the sacculus of the inner ear, exposing the sagittal otoliths. Using forceps, I removed both sagittal otoliths. The otoliths were rubbed in fresh water to remove the otolithic membrane, blotted with a paper towel, and allowed to air dry. Dry otoliths were stored in labeled 1.5-ml microcentrifuge tubes.

I made a lengthwise incision along the ventral surface of the abdomen in order to open the abdominal cavity for rapid saturation with fixative. Stomach contents were fixed using a 10% formalin solution (3.9% formaldehyde by volume) injected by a 5-ml disposable Pasteur pipette into the stomach through the esophagus. Whole fish specimens were placed into 19-L plastic buckets containing a 10% formalin solution and transported to a laboratory at UAF.

Length, weight, and growth analysis

The relationship between weight and length for Bering ciscoes collected in this study is expressed in the form:

$$\log_{10}(weight) = a' + b \cdot \log_{10}(length). \qquad (1)$$

This relationship shows a linear regression of the logarithmically transformed weight (g) and FL (mm) data, where a' is the y-intercept and b is the slope of the linear regression. The a' term expresses the expected theoretical weight of a fish at emergence, while b expresses change in weight relative to change in FL as a fish grows, (i.e., change in body shape of a fish over time). If b is equal to 3.0, then fish growth is isometric, or body shape remains the same as a fish grows. If b differs from 3.0, then fish growth is allometric, or body shape changes as a fish grows. A slope greater than 3.0 indicates an increase in relative girth during growth, while a slope less than 3.0 indicates a decrease in relative girth (Anderson and Neumann 1996).

I calculated a von Bertalanffy growth function using Fishery Analyses and Simulation Tools software (FAST) (Slipke and Maceina 2000). The von Bertalanffy growth function is used to predict the value of a fish's fork length at age t (L_t). The equation for the growth function is:

$$L_t = L_\infty(1 - e^{-k(t - t_0)}), \qquad (2)$$

where L_∞ is the maximum theoretical fork length for the species, k is the Brody growth coefficient or the rate at which the growth curve approaches the asymptote, and t_0 is the theoretical time at which fish length equals 0 (Wootton 1992).

Age estimation of Bering cisco

To prepare otoliths for aging, I followed methods described by Maceina (1988). To thin-section otoliths, I mounted an otolith anterior end down in thermoplastic cement on a petrographic microscope slide (27 x 46 mm). Using a horizontal diamond grinding wheel, I ground from the posterior end of the otolith toward the sulcus, stopping when I reached the center plane of the otolith nucleus. I inverted the otolith, placing the center plane of the nucleus on the microscope slide, and removed the remaining tissue from the anterior end. I transferred slides to the grinding wheel of a Hillquist Thin Section Machine (Hillquist Incorporated, Denver, Colorado) and ground otoliths to a thickness of approximately 300 to 350 μm.

To estimate age for each fish using otolith thin sections, I followed the procedure described by Chilton and Beamish (1982). Under a compound microscope, thin sections showed a central opaque region surrounded by alternating thin translucent and opaque bands. Opaque regions appear dark, while translucent regions appear light. The outer margin of the central opaque region marks the age-0 annulus, and the outer margin of the first translucent band marks the age-1 annulus. Outer margins of consecutive translucent bands mark each consecutive annulus. The age of each fish in years is analogous to the number of annuli appearing in the otolith thin section. These fish were captured in August, so the outermost band, which was translucent, was not counted as an annulus. I viewed prepared thin-section slides under a compound microscope with transmitted light at 40-100x magnification (Maceina 1988). I counted the annuli of each otolith thin-section and recorded this number as the age of each fish in years.

Diet analysis

I incised the stomachs and esophagi of the preserved Bering cisco specimens and removed the formalin-fixed contents. I sorted the contents into two prey types (invertebrates and stickleback species), and recorded the mass (wet) of each of the two prey types to the nearest 0.01 g. From these data, I calculated a mean percent composition by mass for all specimens (Bowen 1996).

Gill raker counts and analysis

Using forceps, I extracted the first left gill arch from each preserved Bering cisco specimen and removed as much of the lamellar tissue as possible without compromising the structure of the arch. Under a dissecting microscope, I counted the number of gill rakers. To determine the upper limb gill raker count, I counted all rakers from the anterior end of the upper limb to the last gill raker before the angle of the arch. To determine the lower limb gill raker count, I counted all rakers from the angle of the arch to the anterior end of the lower limb. Gill rakers located at the angle of the arch were included with the count of the lower limb (Hubbs and Lagler 1964). I recorded gill raker counts in the notation established by Hubbs and Lagler (1964), which is the number of upper limb + number of lower limb = total number. McPhail (1966) first described the systematic variation between Bering cisco and Arctic cisco, which distinguishes them as unique species. Bickham et al. (1997) also described Bering cisco gill raker counts in comparison with Arctic cisco.

Results

In August 2005 and 2006, Bering ciscoes were collected from 18 sampling sites. Salinity measurements at these sites ranged from 1 to 30 PSU at a depth of 30 cm. The median catch per unit effort (CPUE) of Bering cisco was 9.0 fish·net hour^{-1} during the study period. I collected 120 Bering ciscoes; 42 fish in August 2005 and 78 fish in August 2006. Other coregonids collected included five broad whitefish, four inconnu, and three humpback whitefish. Bering cisco comprised 90.9% of all coregonids collected. I was able to identify the sex of six individuals; each of these fish was a female with immature ovaries. The remaining captured fish possessed immature gonads in a condition that did not allow sex identification with use of a dissecting microscope.

Bering ciscoes ranged in FL from 146 to 490 mm, with a mean and median FL of 321 mm and 348 mm, respectively. The length-frequency distribution showed that most fish (53%) ranged in FL from 320 to 379 mm (Table 2.1; Figure 2.1). Fish ranged in weight from 32 to 735 g, with a mean and median weight of 304 g and 345 g, respectively. The weight-frequency distribution showed that 29% of fish ranged from 350 to 450 g, and 12% of fish weighed less than 50 g (Table 2.2; Figure 2.2). The weight-length relationship for Bering cisco was calculated as $\log_{10}(weight) = -4.3371 + 2.7082 \cdot \log_{10}(length)$ (Equation 1; Figure 2.3).

I determined the age of 103 Bering ciscoes using otolith thin-sections. All but one of these fish ranged in age from 0 to 6 years, the exception being one age-11 fish. The median age was 3 years, and age-3 individuals comprised 37% of fish captured (Figure 2.4). At a frequency of 15%, age-0 fish represented the third largest age class,

Table 2.1 Age-length key showing mean fork length (FL) at age for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006. Length is fork length to nearest 1 mm.

		Sample Allocation Per Age Group							
Length Class (mm)	Number in Length Class	0	1	2	3	4	5	6	11
140	9	9							
160	5	5							
180	2		2						
200	1	1							
220	2			2					
240	8			5	3				
260	1				1				
280	8			3	5				
300	4				3	1			
320	10				8	2			
340	24		1		11	7	4	1	
360	14				5	4	2	3	
380	8					3	2	3	
400	2				1	1			
420	3				1	1	1		
440	1						1		
460	0								
480	1								1
Total	103	15	3	10	38	19	10	7	1
Mean FL		162	237	259	331	362	381	373	490

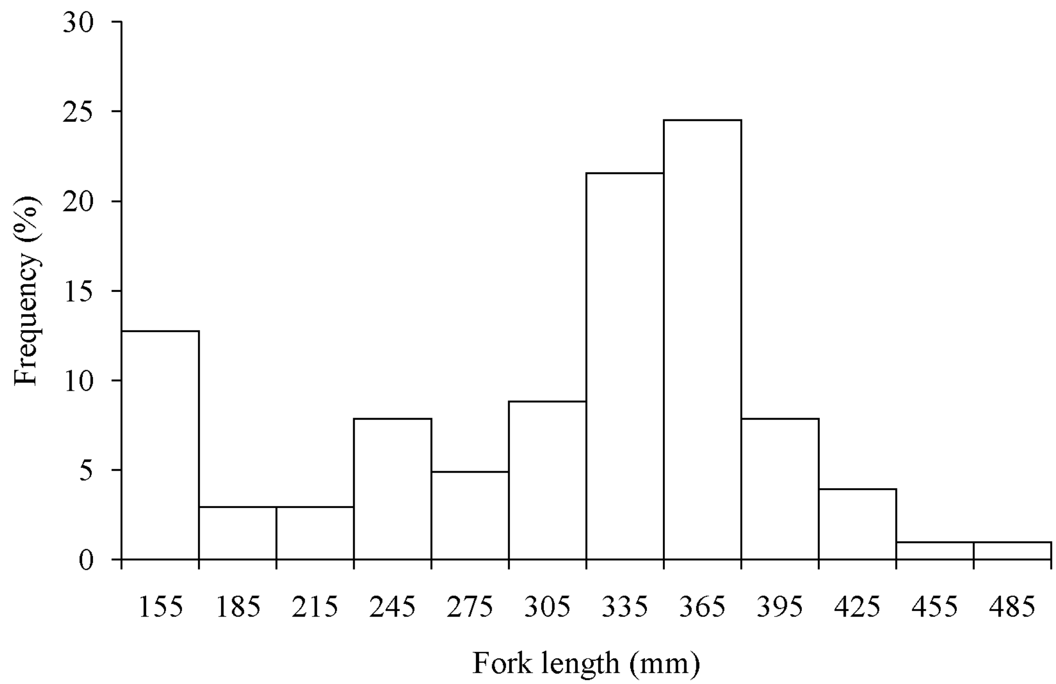

Figure 2.1. Length-frequency distribution for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006 (n = 102).

Table 2.2. Age-weight key showing mean weight at age for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006. Weight is to nearest 1 g.

		Sample Allocation Per Age Group							
Weight Class (g)	Number in Weight Class	0	1	2	3	4	5	6	11
50	12	12							
100	4	3		1					
150	11		2	6	3				
200	4				4				
250	9			3	5	1			
300	5				4	1			
350	16		1		8	5	1	1	
400	14				7	3	3	1	
450	6				2	1	1	2	
500	6					3	2	1	
550	3						1	1	1
600	0								
650	2					1	1		
700	2				2				
Total	94	15	3	10	35	15	9	6	1
Mean Wt.		47	231	151	322	406	474	456	510

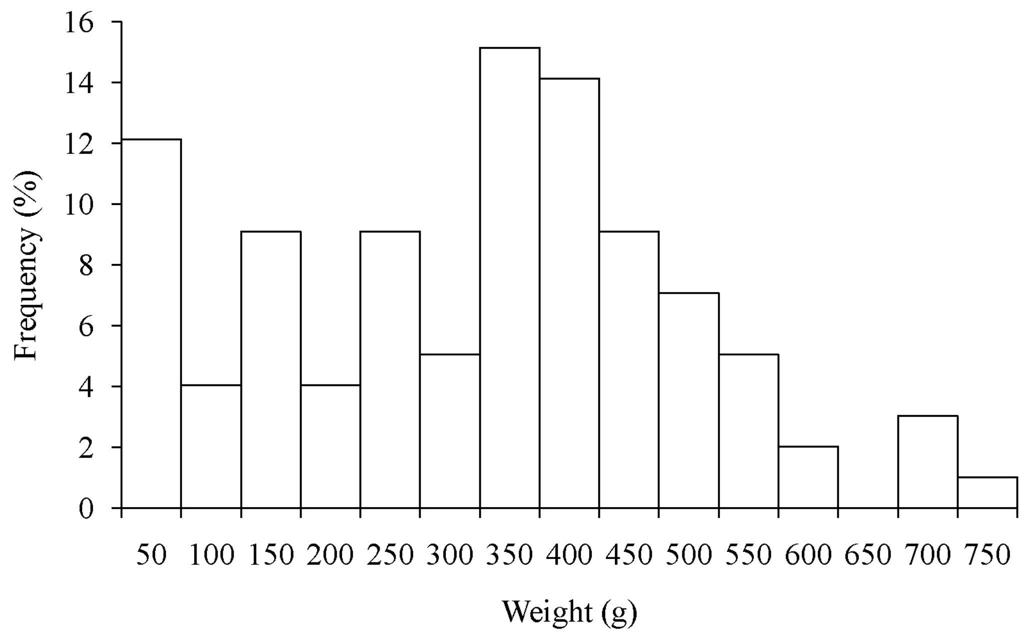

Figure 2.2. Weight-frequency distribution for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006 (n = 100).

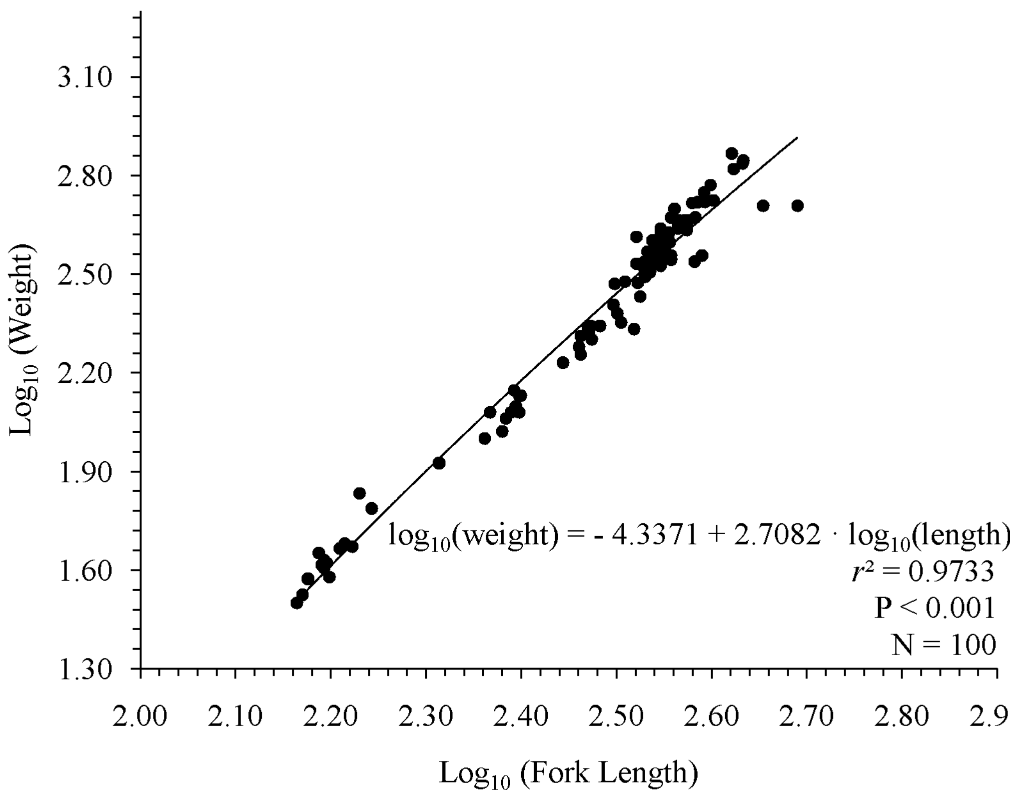

Figure 2.3. Weight-length relationship for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006.

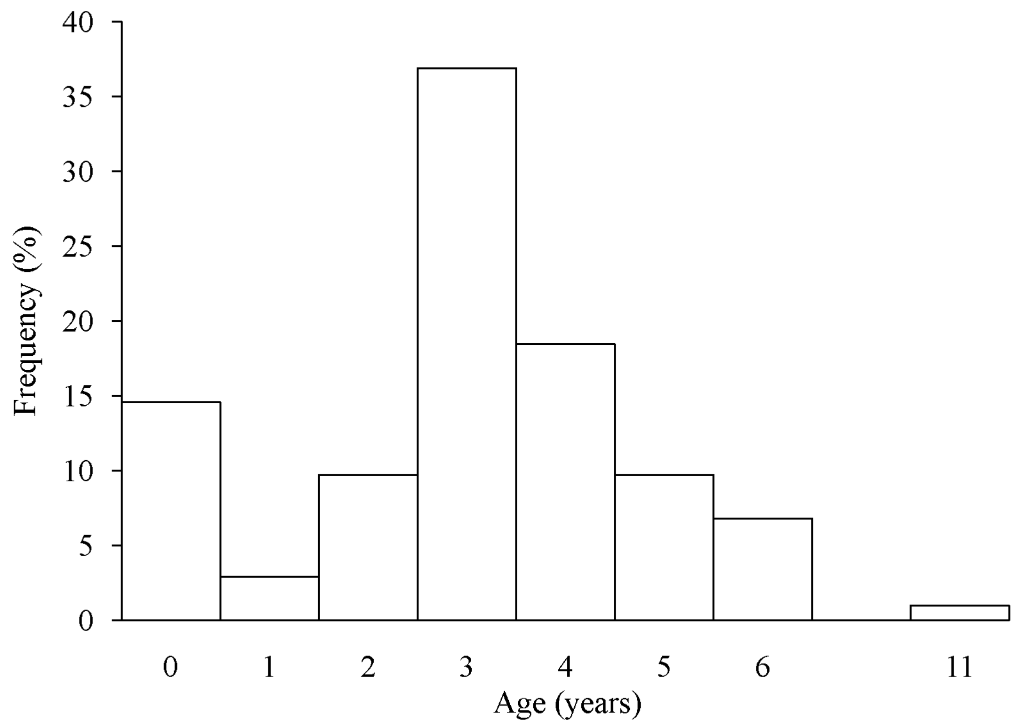

Figure 2.4. Age-frequency distribution for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006 (n = 103).

occurring with greater frequency than age classes 1, 2, 5, and 6 (Table 2.1). The youngest age class represented the smallest fish sampled; age-0 fish ranged in FL from 146 to 206 mm (Table 2.1) and from 32 to 84 g in weight (Table 2.2).

The von Bertalanffy growth function for Bering cisco was calculated as $L_t = 520.35(1 - e^{-0.203(t + 1.487)})$ (Equation 2), with an estimated theoretical maximum fork length of 520 mm (Figure 2.5). The one age-11 fish collected had a fork length of 490 mm (Table 2.1). The next oldest age class of fish collected was age 6, with a mean fork length of 373 mm. The youngest mature fish collected were age 4, with a mean fork length of 362 mm. Age-0 fish had a mean FL of 162 mm and, except ages 5 and 6, each older age class subsequently increased in mean FL.

I examined the stomach contents of 82 Bering ciscoes, and 17 (21%) of these fish had empty stomachs. Food observed in stomach contents included remains of both ninespine and threespine sticklebacks, amphipods, euphausiid shrimp, and one coleopteran. I classified stomach contents as either sticklebacks or invertebrates. Of the individuals with stomachs containing food (n = 65), 85% had either consumed sticklebacks exclusively or had consumed a combination of sticklebacks and invertebrates. The remaining 15% of Bering ciscoes had consumed invertebrates exclusively. The mean mass of stomach contents for individuals feeding exclusively on sticklebacks was 3.92 g, with a range from 0.01 to 16.43 g. Bering ciscoes feeding exclusively on invertebrates had a mean stomach content mass of 1.33 g, with a range from 0.12 to 4.63 g. Of the Bering ciscoes with stomach contents, 8% contained a combination of sticklebacks and invertebrates. For these fish, the mean mass of

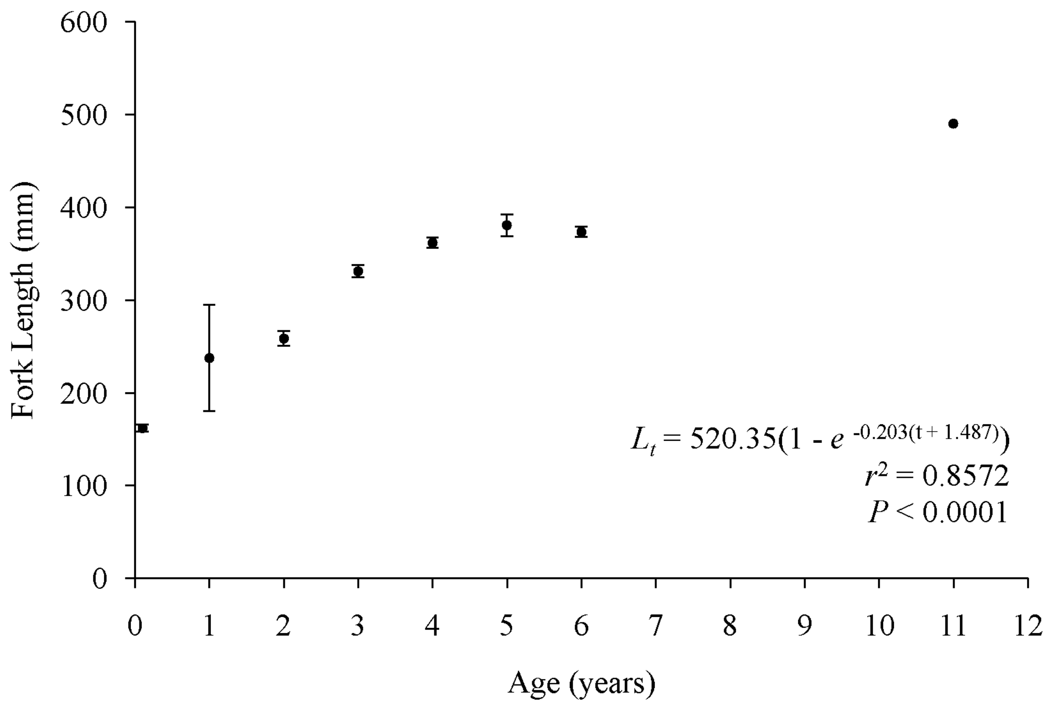

Figure 2.5. Mean length at age and von Bertalanffy growth function for Bering cisco collected in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006.

sticklebacks consumed was 8.83 g, with a range from 2.81 to 18.86 g. The mean mass of invertebrates consumed by these fish was 0.57 g, with a range from 0.06 to 1.72 g.

Bering ciscoes that had consumed prey ranged in FL from 240 to 452 mm, and from 105 to 660 g in weight. These fish consumed a total of 201.9 g (93%) of sticklebacks and 15.36 g (7%) of invertebrates. Individuals with a FL greater than or equal to 375 mm (Figure 2.6) and a mass greater than or equal to 500 g consumed exclusively sticklebacks (Figure 2.7). Among fish with a FL less than 325 mm, sticklebacks comprised on average 68% of stomach content weight. Among fish with a FL 325 mm and greater, sticklebacks comprised an average of 98% of stomach content weight. Among fish weighing less than 350 g, sticklebacks comprised on average 85% of stomach content weight. Among fish weighing 350 g and greater, sticklebacks comprised an average of 97% of stomach content weight.

I removed the first left gill arch from 80 Bering ciscoes and counted the upper and lower limb gill rakers. Among 78 of the Bering ciscoes in this study, the lower limb gill raker counts ranged from 21 to 24 (median = 22). Of the two remaining individuals, one had a lower limb gill raker count of 26 and the other 27. The range of lower limb gill raker counts was not normally distributed with high skewness (*ses* = 0.9296) and positive kurtosis (*sek* = 4.8466). I compared the lower limb gill raker counts to Bering cisco gill raker counts of two other studies which shared a similar range (Figure 2.8). McPhail (1966) observed lower limb gill raker counts that ranged from 21 to 25 (n = 56; median = 23), while Bickham et al. (1997) observed gill raker counts which ranged from 21 to 24

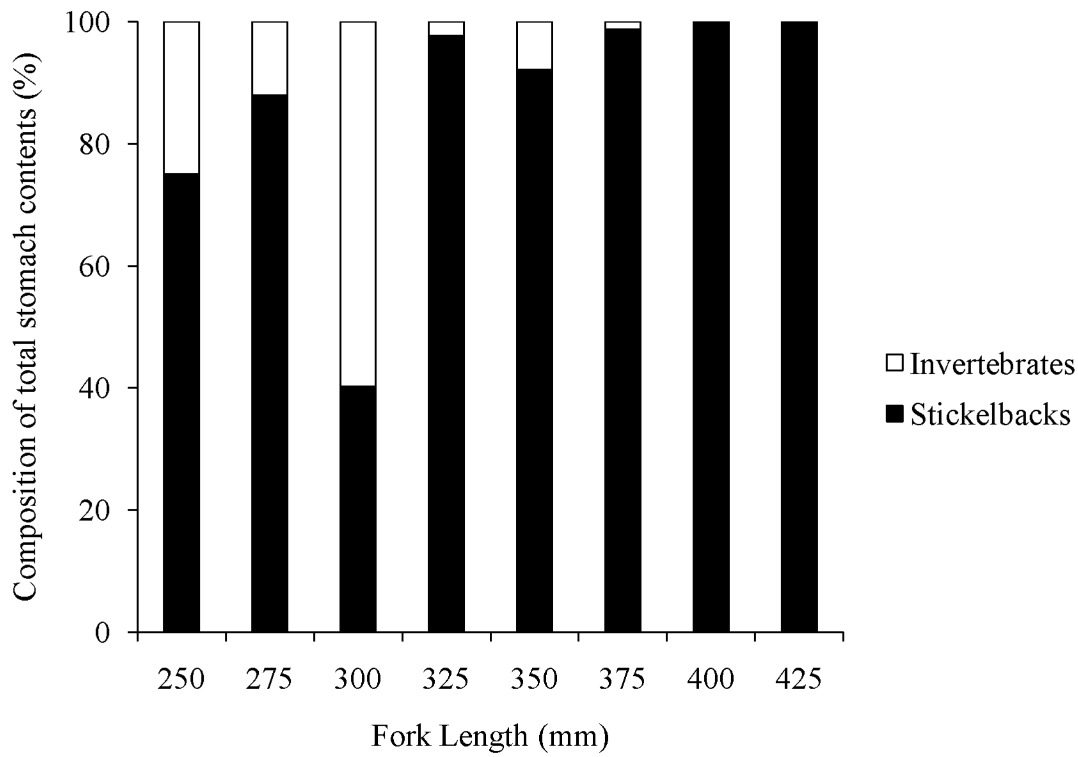

Figure 2.6. Composition of stomach contents by mass in relation to fork length of Bering cisco, in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006. Stomach contents included threespine and ninespine sticklebacks, amphipods, euphausiid shrimp, and one coleopteran. Fork length begins at the axis value beneath each column.

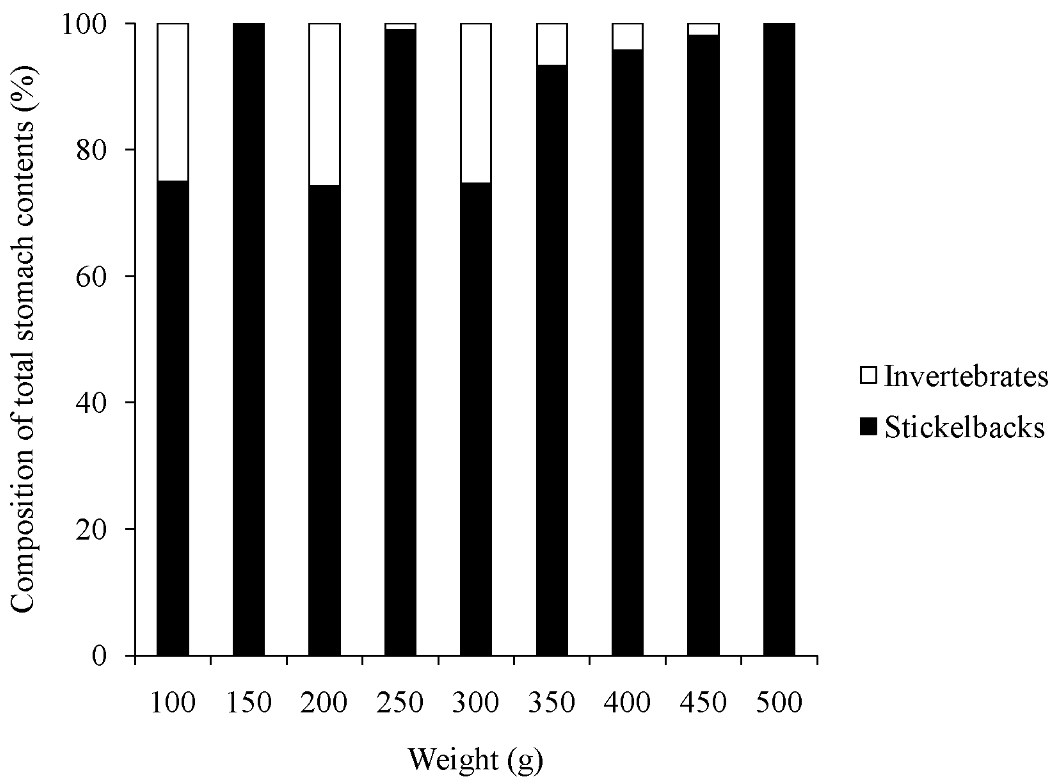

Figure 2.7. Composition of stomach contents by mass in relation to body weight of Bering cisco, in the Kun and Black rivers, Yukon River delta, Alaska, August 2005 and 2006. Stomach contents included threespine and ninespine sticklebacks, amphipods, euphausiid shrimp, and one coleopteran. Weight begins at the axis value beneath each column.

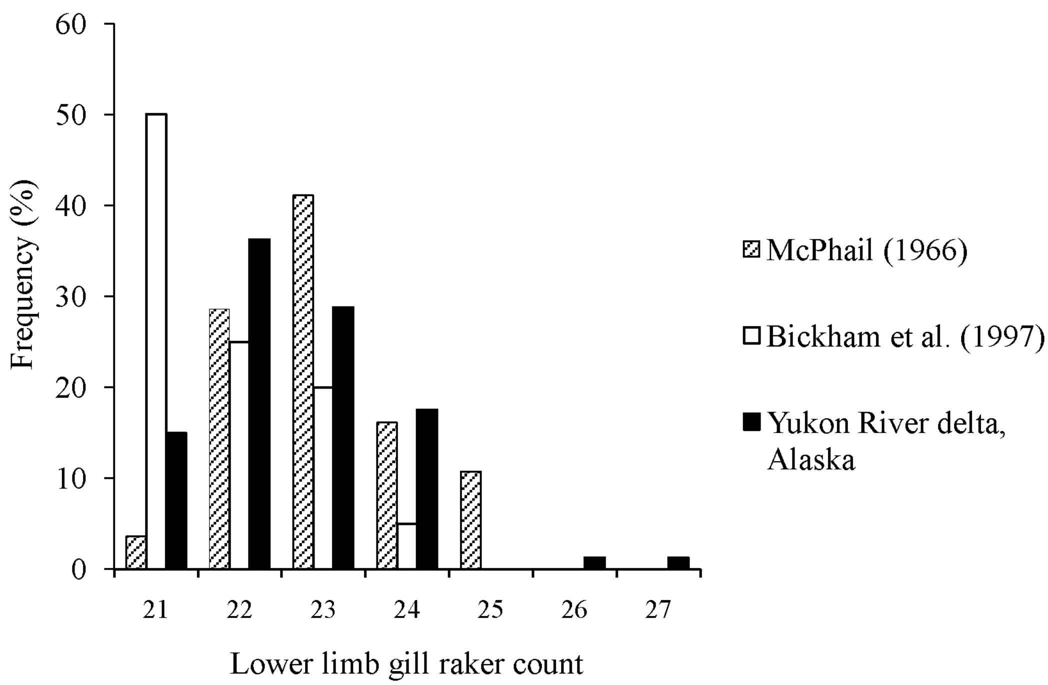

Figure 2.8. Frequency distribution of lower limb gill raker counts of Bering cisco from three studies in coastal Bering and Chukchi seas, Alaska.

(n = 20; median = 21). The ranges of gill raker counts in the latter two studies also were not normally distributed.

Discussion

The objective of this study was to collect Bering ciscoes in coastal habitats in the Yukon River delta, estimate catch-per-unit-effort, record length and weight by age class, estimate growth rate, analyze stomach contents, and compare gill rakers to previous studies. Most of Bering ciscoes that were collected during this study in brackish water; however, some fish were collected in areas with salinity equivalent to sea water (≈30 PSU), which is consistent with other studies (McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980; Mecklenburg et al. 2002). The species composition of fish collected and the CPUE data suggest that Bering cisco was the predominant whitefish species within the study area.

All Bering ciscoes were either immature (ages 0 to 3) or mature non-spawning adults (ages 4 to 6, age 11) with undeveloped gonads. Age at maturity for Bering cisco is 4 years as determined by the ages of spawning adults collected by Alt (1973b) and current, unpublished studies (R. Brown, USFWS, unpublished data). The predominance of immature fish ages 0 through 3 indicates that Bering cisco are recruited to coastal Bering Sea habitats following emergence from larval life stages and transport downriver from spawning sites. The presence of non-spawning adults, ages 4 through 6, may indicate the possibility of some variation in the timing of recruitment to spawning stocks. Alternately, these individuals may also be adults that had spawned, and then returned to rearing habitats to feed before spawning again. Because Bering cisco are known to spawn in late September and early October (ADFG 1981; Brown 2000), it is very unlikely that age-4 and older fish with undeveloped gonads collected in the coastal habitat in August would be able to spawn in the same year.

Fork lengths of Bering ciscoes were dissimilar in range (146 to 490 mm) to fish collected in earlier studies within coastal waters, although they did show some overlap. McPhail (1966) described museum specimens of Bering ciscoes that had been collected throughout their coastal range in Alaska, which ranged in FL from 40 to 380 mm. Alt (1973b) collected specimens on the Seward Peninsula coast, Alaska, and recorded fish with a FL range from 235 to 350 mm. Although it is not clear which gear types were used to collect fish in the study described by McPhail (1966), Alt (1973b) used a multi-panel experimental net to collect fish. As a result, it is difficult to determine the source of any differences in FL range among these three studies solely based on gear types. In my study, the largest fish had a FL of 490 mm, similar to the longest individual recorded by Alt (1973b; 480 mm), which was a spawning female collected in the Yukon River. The majority of individuals had a FL of 240 mm or greater and weighed 250 g or greater. The largest Bering cisco captured in my study weighed 735 g, larger than the most massive fish recorded to date (McPhail and Lindsey 1970; 450 g). The predominant use of a 38-mm bar mesh net for sampling in this study may have biased fish collection in favor of larger individuals, in that larger fish were more susceptible to capture than smaller fish. Smaller fish were only captured on two occasions when I deployed a multi-panel experimental gill net. Future studies which utilize experimental nets may show more even distribution of length and weight classes in the study area (Jensen 1986).

The von Bertalanffy growth function was calculated as $L_t = 520.35(1 - e^{-0.203(t + 1.487)})$, with a maximum theoretical FL of 520 mm for Bering cisco. Mean FL increased with age, except from ages 5 to 6 where mean FL decreased, which most likely was due to the small sample for age-6 fish. The increase in mean FL throughout most age classes indicates the normal pattern of positive growth observed in most fishes (Wootton 1992; Moyle and Cech 2000).

Previous studies have observed that the Bering cisco diet consists primarily of invertebrates in marine and estuarine habitats. McPhail and Lindsey (1970) observed amphipods in the stomachs of Bering ciscoes collected in coastal habitats throughout their geographic range. Alt (1973a) observed that Bering ciscoes collected in coastal waters fed primarily on invertebrates and cottids. Blackburn et al. (1979) recorded that Bering ciscoes collected along the Alaska Peninsula coast fed on calanoid copepods. In my study, Bering ciscoes with stomach contents fed both on invertebrates and sticklebacks. Some fish contained only invertebrates, while others contained only sticklebacks. In addition, the stomach contents of some fish contained a combination of both invertebrates and sticklebacks. Except for the group of individuals ranging from 275 to 300 mm in FL, stomach contents of all fish examined consisted primarily of sticklebacks. In order to determine whether Bering cisco select sticklebacks over invertebrate prey resources, future research will need to apply a selectivity analysis to compare the relative abundance of prey types in the environment to their relative abundance in the Bering cisco diet. Such a study would require extensive sampling of potential prey resources in the estuarine habitats of the Yukon River delta, description of habitats selection both of Bering cisco and of prey species, as well as a quantitative evaluation of Bering cisco digestion (Strauss 1979).

Diet analysis data indicate that larger Bering ciscoes had the largest percentages of sticklebacks in their diet. Smaller fish may be less able to feed on sticklebacks due to limited gape. Fish gape width (i.e., height, width, and area) in many species is positively correlated with fish length (Ivlev 1961; Keast and Webb 1966; Persson 1990; Juanes 1994) and, as a result, most fish undergo ontogenetic diet shifts as they increase in size (Persson 1990; Nilsson and Bronmark 2000; Scharf et al. 2000). Future research may correlate Bering cisco length and the selection of larger prey, such as threespine and ninespine sticklebacks.

In addition to the relationship between predator length and prey size, the quality of sticklebacks as a food resource is a factor. In proximate-composition analyses of prey fishes in the Yukon River delta coast, Ball et al. (2007) found that sticklebacks had higher total energy content relative to other species of forage fish. Ninespine sticklebacks had a lipid content of 24% of total body mass, while threespine sticklebacks had a lipid content of 11%. Least cisco had a lipid content of 21% of total body mass, while pond smelt *Hypomesus olidus* had a lipid content of 17%. The remaining fish species examined ranged in lipid content from 4% to 9%. Piscivorous fishes in the region can obtain the highest energy content per gram by selecting for sticklebacks, least cisco, and pond smelt (Ball et al. 2007), which suggest that Bering cisco select ninespine and threespine sticklebacks for their high energetic value. Rearing in the coastal marine environment is certainly a crucial stage in the life history of Bering cisco. Recruitment of juveniles to these habitats provides abundant food resources for development to maturity and spawning. Sticklebacks may be an essential forage prey resource for Bering cisco, providing a high-energy food source prior to their long spawning migrations.

My study also recorded Bering cisco lower limb gill raker counts. Researchers have used gill raker counts in whitefish for the identification of stocks (Lindsey 1981; Begg and Waldman 1999) and sympatric morphotypes (Amundsen et al. 2004; Kahilainen and Ostbye 2006). It is the phenotypic characteristic most often used to determine taxonomic differences in coregonids from stocks to genera (Lindsey 1981). Previous studies of Bering cisco have examined lower limb gill raker counts in fish collected throughout coastal Alaska (McPhail 1966; Bickham et al. 1997). Ranges of the three studies were similar; however, my study observed two fish with lower limb gill rakers of 26 and 27. McPhail also observed several fish with 25 gill rakers. Therefore, there is some variation in the ranges of Bering cisco gill rakers, the source and extent of which have not been determined.

Gill raker counts from my study may be applied to stock identification of Bering cisco in future research. For example, these data can be compared with studies that attempt to distinguish Bering cisco spawning stocks by morphological characteristics. In a current study of spawning Bering cisco in the Yukon, Kuskokwim, and Susitna rivers, researchers have identified some variation in lower limb gill raker counts (R. Brown, USFWS, personal communication). Preliminary data from the latter study have shown that Bering ciscoes of the Yukon and Kuskokwim rivers have a range of 20 to 24 lower limb gill rakers, while Susitna River fish have a range of 21 to 27 lower limb gill rakers.

Although data collection and analysis are incomplete, this research suggests differences in gill rakers between different Bering cisco stocks. My data, in addition to the data of other studies I have cited, provides additional support for these results.

An experimental commercial fishery which exploits Bering cisco currently exists near the mouth of the Yukon River (S. Buckelew, ADFG, personal communication). Each Spetember and October since 2005, the ADFG has permitted the harvest of 4,536 kg of Bering cisco and least cisco for smoked whitefish markets in New York City (Demarban 2010). Since 2005, commercial fishers have harvested an average of 2,551 kg of Bering cisco in this fishery, with a minimum harvest of 164 kg in 2005 and a maximum of 4,492 kg in 2009 (Newland 2005; Clark 2006; Horne-Brine 2008; Hildebrand 2009; Newland and Buckelew 2010). An Emmonak, Alaska fish processor and some lower Yukon River commercial fishers have expressed their desire for the ADFG to expand the fishery tenfold to 45,360 kg per year. The fish processor has argued that Bering cisco stocks are abundant enough for expanded harvests, and has claimed that Bering cisco play a relatively small role in rural Alaskans' subsistence diets (Demarban 2010). It was clear from my ethnographic research described in Chapter 1 that Bering cisco are a very important subsistence resource for many Yup'ik Eskimo families (see Chapter 1). This is true partly because subsistence fishers considered Bering cisco to be a high quality fish that is rich in oil and partly because the fish are available through most of the year.

The ADFG is monitoring Bering cisco stocks closely, and they are developing a research plan to advance understanding of Bering cisco biology and population status.

Research on the commercial fishery records FL, weight, age, sex, and spawning condition of Bering cisco (Newland and Buckelew 2010). The current conclusion is that the ADFG does not have sufficient biological and population data to expand the harvest allocation of the fishery (Newland and Buckelew 2010). An important research question to be considered is whether the fish in the lower Yukon River represent a mixed population of Yukon and Kuskokwim river fish. Expanding a commercial fishery on a mixed population could threaten the health of the relatively small Kuskokwim River stock (Demarban 2010; R. Brown, USFWS, personal communication). Implementing the results of this study to develop research questions regarding stock characteristics, life history, and feeding ecology will be essential in future research and management of Bering cisco throughout its range in Alaska.

This study examined Bering cisco in the Yukon River delta coastal marine habitat in order to improve understanding of the species' population and life-history characteristics. The study's description of age structure and growth of fish shows that Bering cisco in the region are immature, non-spawning fish, and likely in a growth stage of pre-spawning development. Diet analysis evaluated a previously unrecorded aspect of Bering cisco life history, indicating that fish fed mostly on threespine and ninespine sticklebacks. An examination of Bering cisco lower limb gill rakers showed that fish from this study had a range of gill raker counts similar to those of other studies (McPhail 1966; Bickham et al. 1997). While data from this study are primarily descriptive of Bering cisco, the implication is that more research on the species is needed. Alaska's Bering cisco populations throughout the coastal Bering and Chukchi seas are an essential subsistence resource for many Alaska Native fishers. Bering cisco is also a target species for a small, experimental fishery in the lower Yukon River, an economically depressed region of Alaska with limited employment opportunities for residents. Fishery managers need to examine key biological characteristics of the species, which would include species distribution, size and age structure, availability of forage fish, and morphological or other traits which could distinguish the known spawning stocks. Until further research is pursued, the effect of harvest on the sustainability of subsistence and commercial fisheries will remain unknown.

Conclusion

This is a study of Bering cisco from two distinct perspectives: traditional Yup'ik knowledge and Western science. The overall purpose of the ethnographic interviews in this study is to record traditional knowledge and experience of subsistence fishers in Scammon Bay, Alaska, regarding local species of whitefish and Bering cisco in particular. The purpose of biological methods of the study is to describe life history and stock characteristics of Bering cisco in the Yukon River delta, Alaska. The integration of these two fields of inquiry recognizes the value of both disciplines to subsistence resource users and to fisheries researchers. The ethnographic study describes Yup'ik traditions regarding subsistence fishing, and explores the cultural significance of Bering cisco as a highly valued fish. The biological study advances knowledge of life history and ecology of Bering cisco, and connects this information to knowledge shared by interview participants.

In ethnographic interviews and participant observations, Yup'ik subsistence fishers described many aspects of Bering cisco life history. These included seasonal migrations, feeding behavior, nutritional quality as a food resource, and regional abundance of fish. Bering cisco was described as a fish that migrates into inland coastal marine habitats each May from the ocean, at which time they are thin and lacking oil. Traditionally, Bering ciscoes were harvested at family fish camps in spring. In the past, families began their annual cycle of moving between fish camps with harvests of this species. Despite the fact that travel to seasonal whitefish camps no longer occurs, Bering cisco is still commonly harvested near Scammon Bay. As a result of the species' abundance and high oil content, people of Scammon Bay maintain the traditional preference for Bering cisco. Interview participants explained that Bering cisco return to rivers and streams inland each spring to feed on the abundant populations of sticklebacks.

Participants in this study also discussed other topics related to subsistence fishing and traditional resource harvests in the area. A significant portion of interviews included discussions of whitefish nomenclature. Names commonly used for whitefish species harvested in the area indicated the complex nature of Yup'ik knowledge of whitefish. Some whitefish names identified fish by their use as a food resource, and others by their life-history characteristics. For example, *imarpinraq* is the common Yup'ik name for Bering cisco, which describes the fish as "the one from the ocean".

Other discussions of whitefish explained historic migrations of least cisco, a species which over the course of 20 to 25 years seemed to be decreasing in abundance. Large numbers of least cisco had been harvested by residents of Scammon Bay in the past, but the species is rarely observed in the area at present. Interview subjects indicated these fish were likely less abundant due to the apparent increase in beaver populations.

Results from traditional knowledge interviews did not merely produce a set of discrete facts about whitefish and subsistence harvests. While people did share many specific observations about natural phenomena, the overall sense of Yup'ik traditional knowledge was that it expressed the place and way of life that the people of Scammon Bay inhabit. Their physical place in the world included humanity, as well as the geography, animals, and plants with which people must interact to survive. With regard to whitefish and Bering cisco, participants expressed that having an intimate knowledge of these fish was essential to the sustainability of Yup'ik lifestyle. For example, Mary Ann Sundown's reliance on Bering cisco and many other species demonstrated her family's ability to inhabit the world and thrive with the fish that shared it. Similarly, people's concern over changes to the landscape with increases in beaver dams showed the complexity with which Scammon Bay residents view their lives in the natural world. From a participant's point of view, beavers had increased due to changes in people's ability or willingness to sustain their traditional lifestyle. They explained that external forces such as decreasing fur prices and increasing fuel prices interacted with the erosion of Yup'ik culture and with people's fondness for non-traditional ways of life. The result of these interactions was destruction of fish habitat by beavers, changes in whitefish abundance throughout the region, and alteration of traditional systems of harvest.

As an ethnographer, I was willing to investigate biological phenomena that were relevant to and supplemental of local fishers' knowledge and experience. My biological research questions pursued topics of interest to subsistence fishers, such as the Bering cisco diet of sticklebacks and its marine life-history characteristics. The sharing of traditional knowledge in Scammon Bay directly informed and supported the biological research aspects of this study.

Specifically, I collected juvenile and non-spawning adult Bering cisco in coastal marine habitats on the Yukon River delta. I recorded length and weight data of Bering cisco specimens, estimated age, described growth relationships, examined and recorded stomach contents, and described morphological data in relation to other Bering cisco studies. Results of this study indicated that Bering cisco of the Yukon River delta inhabit coastal marine and inshore brackish water habitats, feeding primarily on sticklebacks. The biological data discussed in this study describes characteristics of Bering cisco diet which have been previously unknown except to traditional fishers, and which will now inform future research on Bering cisco feeding ecology.

These observations extend scientific knowledge of Bering cisco, with the expectation that it will assist future researchers in continuing investigations into this poorly understood species. To develop proper management strategies for Bering cisco, scientists must expand their investigation of the biology and life-history characteristics of this species. There are several fundamental areas of inquiry that may help to guide research of Bering cisco. First, it is essential that scientists describe basic stock-assessment characteristics of juveniles in coastal marine habitats to predict species abundance for the purpose of managing commercial and subsistence fisheries. Age-class data can be applied to a stock-recruitment model for Bering cisco, which would represent an important advance in the ability to manage the fishery. Also, with continued sampling of Bering cisco, quantitative growth relationships can be refined and applied to predicting the number of recruits to spawning populations. Accurate predictions of age class and spawning population sizes can inform managers in setting harvest limits for the commercial fishery.

Descriptions of prey selection in productive rearing habitats will guide studies of the relationship between Bering cisco feeding ecology and anadromy and amphidromy as adaptive strategies. While this study observed that sticklebacks comprised a substantial portion of juvenile Bering cisco diet, it only introduced feeding ecology of the species.

The diet analysis data from this study suggest a possible relationship between Bering cisco growth and ontogenetic diet shifts. Future research in the study region should investigate trophic-level interactions of primary productivity, abundance of planktivores, and their relationship to Bering cisco growth rate, lipid content, and spawning readiness. Such research may be able to examine how critical sticklebacks are in determining Bering cisco fitness as an anadromous or amphidromous species.

It is important to record morphological characteristics which may lead to identification of the three known Bering cisco spawning stocks. It is unknown whether there are any morphological characteristics that would allow researchers to distinguish different stocks. Identification of Bering cisco spawning stocks may be essential in preventing overharvest of the potentially smaller Kuskokwim River stock during commercial fishing harvests. Current research by the USFWS suggests that Bering cisco gill rakers may be a distinguishing morphological characteristic, and the three spawning stocks of fish are being examined to determine this distinction. My research provides additional gill raker data which will support these studies.

Biological data such as these and other descriptions of Bering cisco explained in this study are helpful in developing a more complete understanding of this species. We can describe a variety of aspects of Bering cisco life history by reviewing these data. They indicate new knowledge of the species which directly supports efforts of Alaska's fisheries managers. In reviewing this study, however, it is clear that there is a great deal more to consider about Bering cisco.

What this study actually teaches us about Bering cisco and other whitefish species is that we can understand fish and other natural resources from different perspectives. In my study, the Western scientific perspective describes Bering cisco through a series of field observations and laboratory analyses. The biological data describe a number of specific and quantifiable characteristics possessed by Bering cisco, such as age, length, weight, growth, and diet. These data describe biological characteristics of the species as it exists in the study area, and provide significant information to fisheries scientists. Scientists can use this study's data to draw inferences about Bering cisco life history and propose new research questions. For example, future research can determine from which spawning stocks Bering cisco of the region originate. This would be helpful in investigating patterns of Bering cisco abundance in Alaska's coastal marine habitats. It would also help predict recruitment of different year classes, which is essential for accurate management of commercial and subsistence fisheries.

While this study's biological data are descriptive of some Bering cisco characteristics, they do not offer the only perspective on this important resource. The traditional Yup'ik perspective is that Bering cisco represents a significant cultural landmark in seasonal harvest cycles. Families traditionally moved to follow different resources as they became available throughout the seasons. An example of Bering cisco as a seasonal cultural landmark can be read in Francis Charlie's descriptions of fish harvests at Anaarciq, where the Bering ciscoes were so plentiful they jumped into his boat. This marked the traditional harvest of Bering cisco and other whitefish before freeze-up, a time for putting away fish in preparation for winter. Mary Ann Sundown provided another example when she explained that the family's annual return to Scammon Bay occurred in December after the Bering cisco migrated out of the river into the ocean. At that time, people moved into Scammon Bay with their supplies of fish, birds, and furs, and the men began preparing for the winter hunting season.

These cultural events demonstrate the seasonal interactions between people and Bering cisco. The fish as a resource marked turning points throughout the year. These turning points grounded families in the natural and essential progression of Yup'ik life, a life of preparing for the next season. Understanding this perspective is just as important as knowing the Western scientific perspective. Science helps managers quantify stocks and set harvest quotas so that families can maintain their access to food and wages. Yup'ik traditions help connect people to their traditional food systems and cultural heritage. Both perspectives are valuable and necessary in sustaining natural resources.

I have characterized this as a story of Bering cisco that began with conversations about whitefish. As an inquisitive person interested in human and biological dimensions of subsistence fisheries, I entered into these conversations with a desire for deeper understanding of Yup'ik perspectives on fish. I quickly discovered the abiding connections which exist between the people of Scammon Bay and the fish they harvest. Participants in the study expressed great pleasure in talking about fish, and greater pleasure in fishing with me. What they communicated was that to know fish, to know Bering cisco, is a clue into knowing the ways of being a traditional Yup'ik person. Bering cisco, as well as many other species of fish and wildlife, is integrated into the daily lives of Yup'ik people in ways that reveal family heritage, social mores, connections to land, and traditional spirituality.

Traditional subsistence fishers in Scammon Bay live within the natural environment according to these complex interactions. What we learn from this study is that indigenous interpretations of the natural world present perspectives unique to those of scientists and managers. Western scientists and resource managers have considerable influence in the lives of indigenous Alaskans. Their methods of inquiry and policies of resource management profoundly affect rural Alaskan families and communities. Recognizing the effects that scientific research and management have on indigenous peoples is essential in understanding Alaska Native perspectives on their lives as fishers, hunters, and gatherers.

A notable example of the successful cooperation between systems of traditional knowledge and natural resource management occurred in the Iñupiaq whaling community of Barrow, Alaska. In 1977 the International Whaling Commission (IWC) estimated the population of the Bering-Chukchi-Beaufort Sea stock of Bowhead whales *Balaena mysticetus* to be approximately 1,300 individuals. As a result the 1978-1979 subsistence whaling harvest quota was set at zero whales, which would have resulted in serious negative consequences for several Iñupiaq communities of the North Slope Borough, Alaska. The population estimate was based on a whale census protocol that was limited by certain assumptions of Western scientists. They assumed that migrating bowhead whales only passed very close to Point Barrow, Alaska each spring and that they stayed in open water because, like humans, they were fearful of sea ice. Census data were based upon whale sightings from onshore locations, and were constrained by weather and sea ice conditions. Iñupiaq whalers claimed to know that the bowhead whale population was likely much greater. They insisted that bowhead whales migrated under sea ice in a path that was approximately 20 km wide, and that most whales were out of sight as they passed through the area (Albert 2001).

Alaska Native and Western scientists applied innovative census protocols which included counting whales with passive sonar devices. Hydrophone arrays were capable of counting whales from 15 to 20 km distant, regardless of weather or sea ice conditions. With guidance from experienced whalers and with rigorous acoustical and statistical analyses, accuracy of bowhead whale census data improved, and population estimates increased more than six fold to 8,200 by 1996 (Albert 2001). Barrow whalers and their research collaborators developed a successful study that coupled traditional Iñupiaq and Western scientific systems of knowledge. As a result, the people of the North Slope region have been able to maintain their traditions of hunting, sharing, and consuming bowhead whales, which are foundations of their cultural heritage.

Yup'ik fishers, biologists, and fisheries managers can be encouraged by the example set by the bowhead whale research program, as well as by my study. Yup'ik traditional knowledge can be applied to whitefish research and management in methods similar to those in Barrow. Subsistence fishers in this study expressed concerns about whitefish populations in the Yukon River delta, and may desire to pursue their concerns with a research and management program. For example, wildlife and fisheries biologists could potentially design a long-term study of beavers in the Yukon River delta with the assistance of Yup'ik residents. Such a study could document traditional and historical knowledge of beavers and whitefish, and apply that to investigations of changing beaver populations and the effects on whitefish migration and rearing. It is possible that collaborative research efforts would observe that beavers have a significant effect on whitefish populations, which would necessarily support effective management of important fish populations like Bering cisco.

This study demonstrates the value of traditional Yup'ik knowledge and Western scientific investigations in developing a story about Bering cisco and the people who depend upon it. It also demonstrates that individuals who desire to link these disciplines can act as liaisons between the two worlds, developing a community of collaboration. Collaboration will lead to management practices that recognize the value of both ways of knowing. Both worlds have the same goal: to support healthy and sustainable fisheries resources. In sustaining Bering cisco populations, we can sustain healthy coastal Yup'ik communities and continue thoughtful and meaningful scientific inquiry into the human, biological, and physical dimensions of Alaska's complex fisheries.

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Appendix A

IRB Protocol Interview Guide

David M. Runfola
(Amended March 2005)

INTERVIEW GUIDE

Combining traditional ecological knowledge with fisheries science to facilitate and guide partnered management and studies on anadromous whitefish

If you would like to conduct this interview in Yup'ik, please tell us now and we will get an interpreter for you.

Following are a number of questions which we will use to guide semi-directed interviews with each subject. Not all subjects may have the knowledge or experience to answer every question. Other questions or discussion points may arise as each interview and the study progress. When inquiring about places related to whitefish life history and whitefish harvests, we will ask subjects to identify place names if they are known or available. We will also attempt to have subjects locate these places on maps, and explain directions or accompany us to these locations.

- What are the Yup'ik names of different whitefish species? How do people tell them apart? (These questions are asked with the aid of photographs of six species of whitefish.)
- Where do you find different species of whitefish? Where do they spend different seasons?
- How many of each whitefish species do you find at different locations during different times of year? Are there times when different species are very abundant or very scarce?
- What are whitefish doing during break-up and freeze-up? How are they affected by ice conditions throughout the fall, winter, and spring?
- When do different species of whitefish migrate? What are the migration routes for each species? Why does each species appear to be migrating? Do migrations occur regularly or irregularly?
- How are migrations affected by water and other environmental conditions (e.g., tides and swells, waves, floods, storms, warm or cold temperatures, changes in temperature)?
- Do whitefish behave differently prior to migrating? Do they gather into large groups? Where and when does this occur?

- Where and when are different species spawning? What do different species look like when they are in spawning condition? When do you notice that males have enlarged testes and females enlarged or numerous eggs? Are there species in which you do not see enlarged testes or numerous eggs? Are there any variations in egg color? Are these variations between and/or within species?
- Describe the habitat that they spawn in. Is the water still or flowing (i.e., in ponds or streams)? Is the water warm or cold? What is the lake bed or river bed like where they spawn (i.e. substrate type.)?
- What can you tell me about juvenile whitefish? Where are they found? Do they migrate?
- What kinds of habitat conditions do different species of whitefish prefer (e.g., water depth, temperature, turbidity, current velocity, vegetation, substrate)?
- What do whitefish eat in the ocean? In fresh water? How does their diet change throughout the year?
- What places, times of year, and gear types are important in catching whitefish? How do you catch whitefish in salt and fresh water?
- What do you look for in selecting an area to catch whitefish? Do you have different criteria for different species?
- Do people travel to catch whitefish? If so where? Why do people travel specifically to these places? Describe what fish camp is/was like for your family?
- What do you do to preserve the fish you catch? How are they stored?
- What species of whitefish do people prefer to catch and why? Are there differences in the quality of the fish during different seasons (e.g., quality of flesh, oil content, diseases, parasites, taste)?
- Do you think the number of whitefish is increasing, decreasing, or staying the same as in the past? Why? What effects have people and other animals had on whitefish or other fish?
- Have there been any environmental changes in the recent past that have affected whitefish behavior and harvests? If so, what effects on whitefish have you noticed?
- Are there any special traditional practices or rules that guide whitefish harvests? Are there special ways to treat whitefish?
- Do you know of any stories told or lessons taught about whitefish?

Appendix B

Photographs of whitefish used in photo elicitation

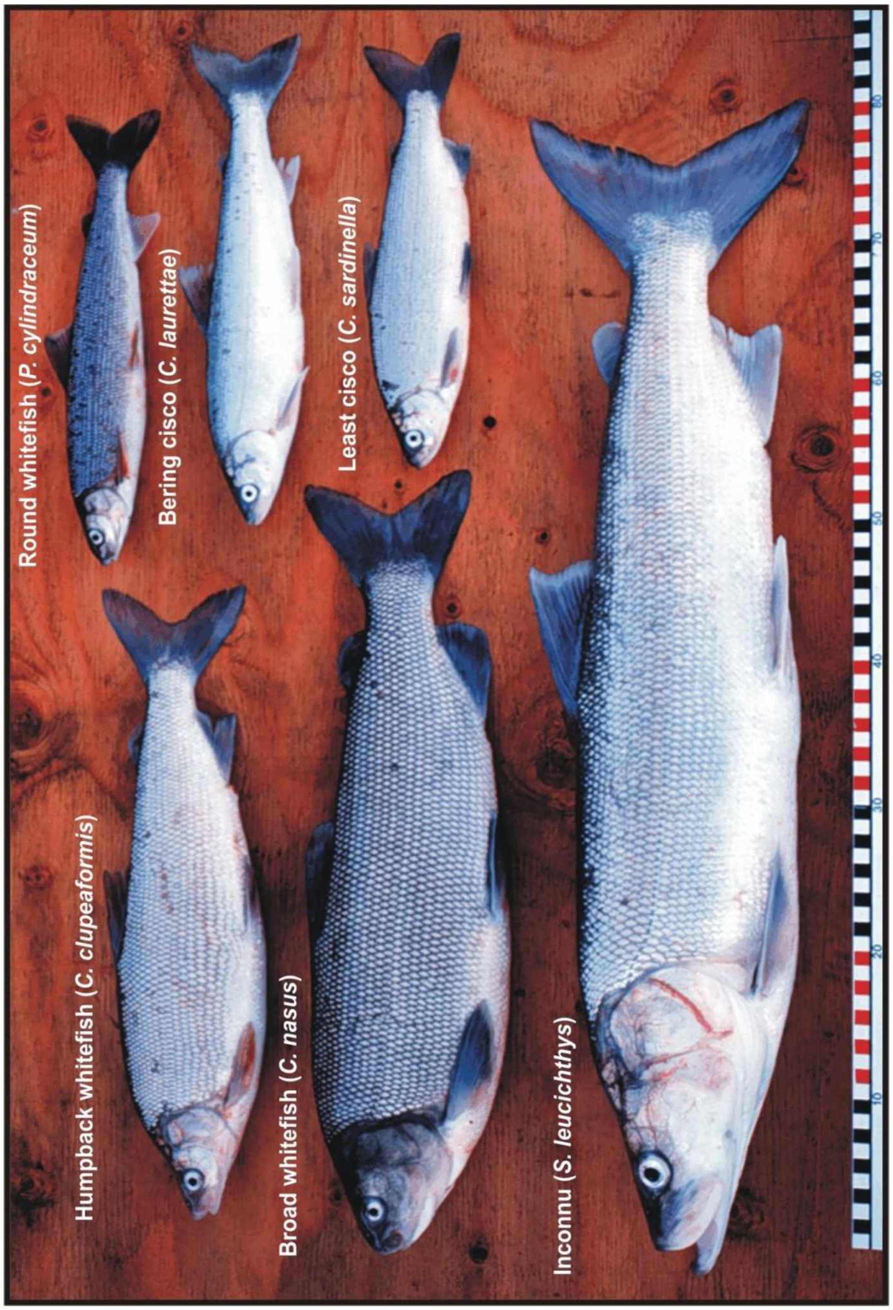

Figure B-1. Photograph of whitefish (subfamily Coregoninae) that inhabit the Yukon River drainage, used in photo elicitation during traditional knowledge interviews in Scammon Bay, Alaska. Ruler shows cm. (Photo by R. Brown.)

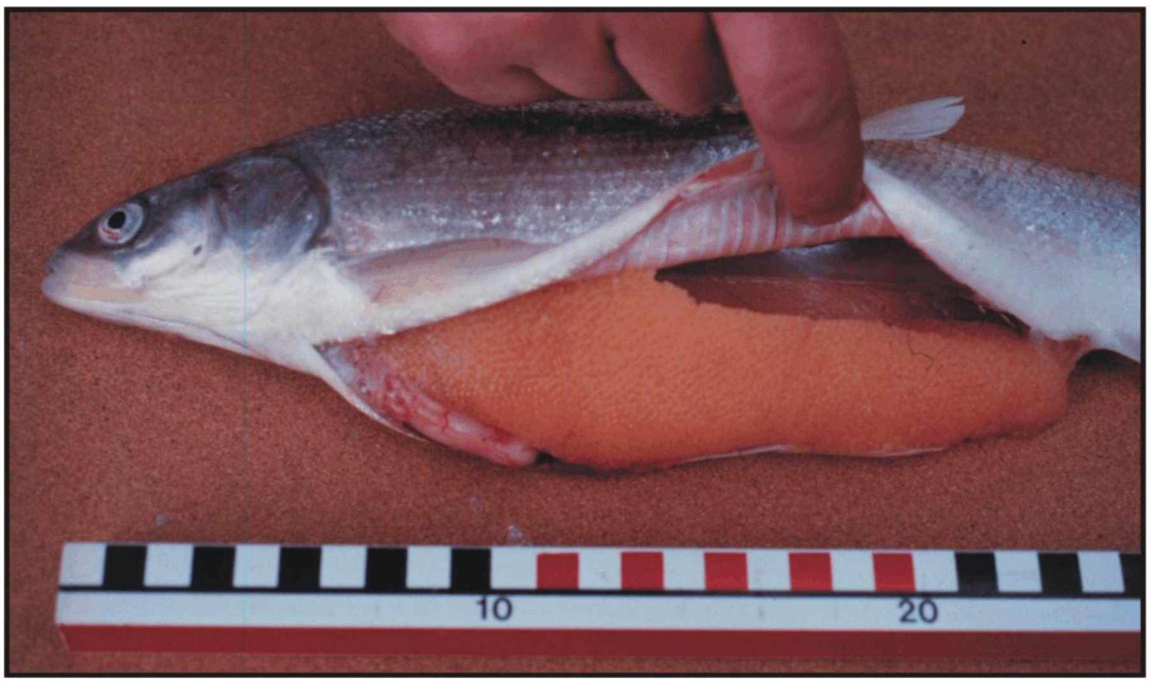

Figure B-2. Photograph of gravid female Bering cisco *Coregonus laurettae* with egg skeins excised and exposed, used in photo elicitation during traditional knowledge interviews in Scammon Bay, Alaska. Ruler shows cm. (Photo by R. Brown.)

Appendix C

IRB and IACUC Continuing Review Forms

UNIVERSITY OF ALASKA FAIRBANKS

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Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

May 22, 2006

To: Gordon Haas, PhD
Principal Investigator

From: Bridget Stockdale, Research Integrity Administrator
Office of Research Integrity

Re: IRB Continuing Review

Thank you for submitting the annual continuing review for the protocol identified below. It has been reviewed and approved by members of the IRB. On behalf of the IRB, I am pleased to inform you that your request to renew this protocol for another year has been granted.

Protocol #:	04-28
Title:	*Combining traditional ecological knowledge with fisheries science to facilitate and guide partnered management and studies on anadromous whitefish*
Level:	Expedited
Received:	May 15, 2006
Approved:	May 22, 2006
Next Review:	Due April 15, 2007

Any modification or change to this protocol must be approved by the IRB prior to implementation. Modification Request Forms are available on the IRB website (http://www.uaf.edu/irb/Forms.htm). Please contact the Office of Research Integrity if you have any questions regarding IRB policies or procedures.

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Institutional Animal Care and Use Committee

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

April 28, 2006

To: Gordon Haas, Ph.D
Principal Investigator

From: Erich H. Follmann, PhD
IACUC Chair

Re: IACUC Continuing Review

On behalf of the University of Alaska Fairbanks Institutional Animal Care and Use Committee (IACUC) I have reviewed the request for renewal of the following assurance. This renewal request has been approved.

Protocol: #04-23

Title: *Traditional ecological knowledge and fisheries science study of Yukon River Delta whitefishes*

Received: April 27, 2006

Approved: April 28, 2006

This Assurance is valid through April 27, 2007, but must be kept current with respect to new methods, techniques and personnel. This protocol will not be eligible for renewal in 2007; rather, it will need to be resubmitted for IACUC review/approval. We recommend submitting two months prior to the expiration date (2/24/07) to prevent any delay in the work covered by this assurance of animal care and use.

Thank you for keeping your IACUC Assurance up to date.

Appendix D

Vita

David Runfola earned a Bachelor of Arts from Fordham University, Bronx, New York. He majored in Philosophy, with a minor in History. He studied secondary education at the University of Alaska Fairbanks (UAF) and earned an Alaska Teacher Certificate in 1998, with endorsements in secondary Social Studies and General Science, and Highly Qualified status in Biology, Physical Science, and Earth Science. His teaching experience includes a variety of subjects in mathematics and the social, biological, and physical sciences. He has taught in Scammon Bay, Alaska, Kongiganak, Alaska, and at UAF with the Upward Bound Program and the Department of Biology and Wildlife. He has also taught elementary science through UAF as a National Science Foundation Fellow at Hunter and Woodriver elementary schools in Fairbanks, Alaska. While attending the UAF School of Fisheries and Ocean Sciences as a graduate student with the Alaska Sea Grant College Program, he investigated traditional knowledge among Yup'ik subsistence fishers and the biology of Bering cisco *Coregonus laurettae*. Since arriving in Alaska in 1992 he has spent several years living and working in rural Alaska communities. He resides in Ester, Alaska with his wife, Rebecca, and their three children.